



Service-oriented product development strategies

Product/Service-Systems (PSS) development

Tan, Adrian Ronald

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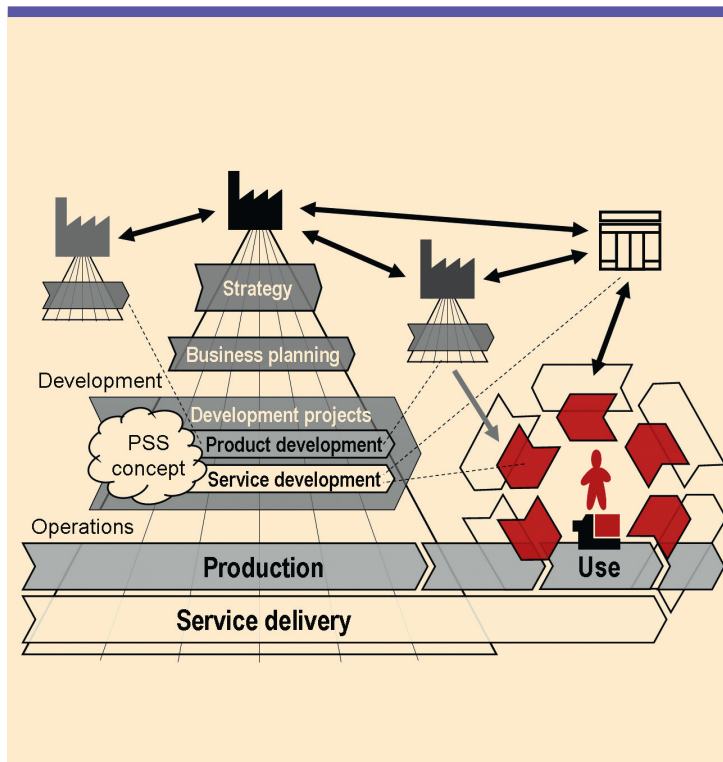
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Service-oriented product development strategies



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Adrian R. Tan
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Adrian R. Tan

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DTU Management Engineering
Department of Management Engineering
(Institut for Planlægning, Innovation og Ledelse)
Technical University of Denmark (DTU)
Produktionstorvet 424
2800 Kgs. Lyngby
Denmark

Tel.: +45 4525 4800

Email: phd@man.dtu.dk

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Service-oriented product development strategies

Adrian R. Tan

Abstract

Manufacturing companies have traditionally focused their efforts on designing, developing and producing physical products for the market. Today, global competition, outsourcing and legislation commend that companies take greater responsibility of their products. This is driving some manufacturers to shift their business strategies from selling products (e.g. photocopying machines) to the provision of services (e.g. document services). Instead of the product itself, the activity and knowledge associated with the use of the product is perceived to be of more value to customers. In the research community, service-oriented approaches that embrace this change of business focus from individual products to total integrated customer solutions are termed *Product/Service-Systems (PSS)*.

The research in this thesis addresses the systematic design and development of PSS solutions in manufacturing firms. Here PSS are understood on three levels in relation to design:

1. *PSS solution* – a system of integrated products and services that companies develop and deliver to customers.
2. *PSS development* – the integrated design processes and development activities that result in PSS solutions.
3. *PSS approaches* – service-oriented business strategies that coordinate PSS development.

Based on an extensive review of the relevant literature and five empirical case studies the following insights were made:

- PSS solutions may be conceptualised by considering the *product life phase systems*, *customer activities* and the *actor network*. These perspectives are fundamental to the understanding of PSS and provide an answer to how they can be more resource-efficient and competitive than traditional product-based business models.
- Development activities related to PSS take place on multiple levels of the organisation in a manufacturing firm, from the formulation of business strategy to individual development projects of products and services, right down to the continuous support of customer activities on an operational level. This identification of PSS related development activities helps companies and researchers in understanding and structuring the development task related to PSS approaches.
- PSS approaches require companies to coordinate their business strategy with their development competencies, product strategy and service offerings in close collaboration with customers and other external partners.

These findings resulted in theoretical models, prescriptive methods and practical tools that are useful for industry, academia and students interested in adopting PSS approaches.

Serviceorienterede produktudviklingsstrategier

Adrian R. Tan

Resumé (in Danish)

Virksomheder i fremstillingsindustrien har traditionelt været fokuseret på at udvikle, fremstille og sælge fysiske varer. I nutidens kontekst af global konkurrence, øget outsourcing og krav om at virksomheder skal tage større ansvar for deres produkter, overvejer nogle producenter at skifte forretningsstrategi fra at sælge produkter (fx fotokopimaskiner) til at levere serviceydelser (fx dokumenthåndtering). I stedet for produktet selv, er det kundens aktiviteter og ydelsen i forbindelse med produktets brug, der fremstår som mere værdifuldt. I den akademiske verden bliver denne serviceorientering imod totale kundeløsninger kaldt for *produkt/service-systemer (PSS)*.

Denne afhandling omhandler den systematiske udvikling af PSS løsninger i fremstillingsvirksomheder. Her kan PSS forstås på tre niveauer i forhold til design og udvikling:

1. *PSS løsning* – et system af integrerede produkter og services, som virksomheder udvikler og leverer til deres kunder.
2. *PSS udvikling* – de integrerede designprocesser og udviklingsaktiviteter, der resulterer i PSS løsninger.
3. *PSS tilgange* – service-orienterede forretningsstrategier, der sørger for koordinering af PSS udvikling.

Med udgangspunkt i en omfattende gennemgang af den relevante litteratur og analyse af fem empiriske casestudier, bidrager denne afhandling med følgende indsigter:

- PSS løsning kan konceptualiseres ved at modellere *produktets livsfase-systemer, kundeaktiviteter* og *aktørnetværk*. Disse perspektiver er grundlæggende for forståelsen af PSS, og giver et svar på hvordan PSS tilgange kan være konkurrencedygtige og mere effektive i udnyttelse af naturressourcer end traditionelle produktbaserede forretnings-modeller.
- Udviklingsaktiviteterne forbundet med PSS finder sted på flere niveauer af organisationen i en fremstillingsvirksomhed: fra formulering af forretningsstrategien, udførende produkt- og service-udviklingsprojekter og frem til løbende støtte af kundeaktiviteter på driftsniveau. Identificering af disse udviklingsaktiviteter hjælper virksomheder og forskere til at forstå og strukturere udviklingsopgaven i forbindelse med PSS tilgange.
- PSS tilgange kræver at virksomheder koordinerer deres forretningsstrategi med deres udviklingskompetencer, produktstrategi og serviceydelser i tæt samarbejde med kunder og andre eksterne partnere.

Denne afhandling har resulteret i teoretiske modeller, metoder og praktiske udviklingsværktøjer, som er nyttige for industrivirksomheder, forskere og studerende, der er interesseret i serviceorienteret produktudvikling.

Preface

This dissertation is the result of a PhD project completed at the Department of Management Engineering (formerly Department of Mechanical Engineering) at the Technical University of Denmark (DTU). The project was initiated in May 2005 and ended in April 2009 which includes 8 months of consulting assignments. The PhD project was funded by DTU.

After graduating from my M.Sc. in mechanical engineering, I worked as a mechanical engineering designer and product development consultant. During this time I enjoyed applying my engineering design skills and experiencing how my ideas evolved into physical artefacts that could be bought in stores around the world. But after 4 years and numerous projects for many different companies I was being to feel the routine of things. Each project from idea to market was a tremendous collaborative development effort and required thousands of man-hours. Although each project was exciting and the resulting product innovative in its own way, at the end of the day it was just another product that was incrementally better than the millions that came before. Considering the amount of effort put in each project I had the feeling much more could be done and greater advances made than just spitting yet another product out on the market.

I was therefore thrilled to get the chance to return back to the 'school bench' and student life to study what lies beyond the development of products. I am therefore eternally grateful to my supervisor, Associate Professor Tim McAloone, for this PhD project and all the support I have received throughout the years. Besides the research topic itself the opportunity to work with Professor Mogens Myrup Andreassen was decisive when I had to figure out if I was ready to say goodbye to a well-paid job. Although perplexing I have greatly appreciated his inspiring 'critical enthusiasm' and wry comments to everyday life! I cannot imagine writing a thesis without him as my co-supervisor.

I am very grateful for all the people that has inspired and contributed to this research project and the fantastic time I have had as a PhD student (write up period excluded!). Amongst these I would like to give a special thanks to:

- my 'partner in crime' Detlef Matzen – it has been invaluable having somebody to spar research ideas with, figure out IT and admin issues before me, and seek consolation with during the tough write up period. Likewise fellow PhD student Giovanna Vianello, thanks for the moral support and supply of Italian delicacies.
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- Dr. Niki Bey for always being available to answer questions regarding environmental issues and for establishing the contact to Steelcase.

- Professor Lars Hein, IPU, for supporting my research activities and allowing me to work as a member of the IPU consulting team.
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- Managing Director Mark Adams, Vitsø, and CEO Hugo Spowers, RiverSimple, for each being such inspiring entrepreneurs and demonstrating to the world “a business less ordinary.” Thanks to both of them for submitting their companies as ‘guinea pigs’ in this research.
- Marketing Director Elisabeth Hjortkjær, SCA Hygiene Products A/S, for the access to employees in SCA and their customers, as well as correcting my poor Danish grammar.
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- all my colleagues at DTU and IPU for creating a fun and pleasant work atmosphere that I will truly miss.
- family and friends for the proof reading, moral support and patience.
- and last but not least, Boris for his encouragement during the write up. Being able to work and be with you in Paris made the write up process a little less dreary.

Paris, January 2010

Adrian R. Tan

“Ancora Imparo”
(“Still I am learning”)

Michelangelo (1475 – 1564)

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1 Introduction

Manufacturing companies have traditionally focused their efforts on designing, developing and producing products to offer on the market. Today, global competition and demands that companies take greater responsibility for products throughout their entire life cycle are driving a change. An increasing number of manufacturing companies are shifting business strategies from selling products (e.g. photocopying machines) to the provision of services (e.g. document management services). Instead of the product itself, the activity and knowledge associated with the use of the product are considered to be of more value to the customer. In the research community this shift of business focus from product-oriented to service-oriented has been called *Product/Service-Systems (PSS)* approaches.

Company	From products...	... to services and total solutions.
Caterpillar	Construction and mining equipment	Financing, insurance, equipment rental, maintenance, support, operator training, etc.
Danfoss	Refrigeration controls and sensors	<i>"Cooling for food retail"</i> – design and specification, system integration, monitoring and reporting, energy management, condition based maintenance, etc.
Dupont	Paint	<i>"Chemical management services"</i> – quality painted surfaces, etc.
Sara Lee/ Douwe Egberts	Coffee	<i>"Coffee solutions"</i> – leasing of coffee machines, supply of coffee, operation and maintenance
Electrolux	Professional washing machines	<i>"Laundry systems"</i> – helping initiators to start a new laundrette or to upgrade old ones, installation, training, financing, etc.
JCDecaux	Bicycles	Self-service bicycle rental schemes
IBM	Computer hardware	Business and software consulting
Rolls Royce	Aircraft engines	<i>"Power-by-the-hour"</i> - fixed fee maintenance back-up service, condition monitoring, predictive maintenance, parts life management, etc.
SKF	Ball bearings	<i>"Engineering consultancy services"</i> - condition monitoring, industrial sealing, lubrication and vibration analysis, etc.
Toshiba Medical Systems	Diagnostic imaging equipment	<i>"Asset management of medical diagnostic systems"</i> - equipment procurement, replacement, management, maintenance, repair and financing
Xerox	Photocopying machines	<i>"Document services"</i> – leasing, maintenance, equipment monitoring, paper and toner supply, document and data management, etc.

Table 1.1 Examples of PSS in industry.

PSS approaches are innovation strategies where companies provide value to their customers through service provision rather than product sales, e.g. by supporting and enhancing the utility of their products throughout their life cycle (Figure 1.1). The principle behind PSS is that value is considered not to be embedded in the physical product, but is created by supporting the customer's activities related to the use of the product. With PSS, manufacturing firms take on greater responsibility for the use or operation of their products, maintenance and/or disposal. It is believed that PSS approaches will enable and motivate companies to reuse, rationalise and enhance their products and services throughout their life phases, with more efficient use of (natural) resources.

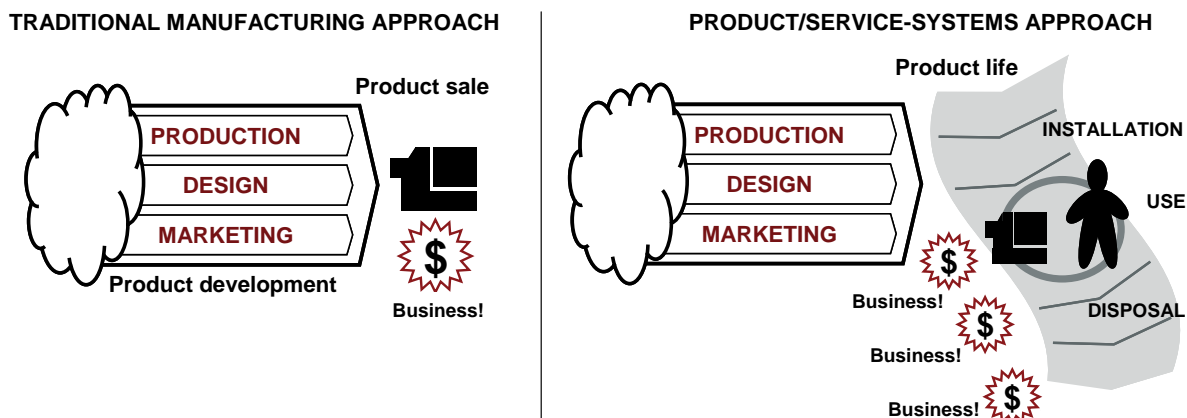


Figure 1.1 Product/Service-Systems (PSS) approaches represent a shift from business based on the value of the exchange of product ownership, to business based on the value of supporting and enhancing the utility of a product throughout its entire life cycle.

In this chapter the background to this research project is introduced. This is done to ground why this research is relevant for industry as well as sustainable development. A brief overview is given of the knowledge that exists in the area to establish where this research aims to contribute to theoretical design knowledge (a deeper investigation of the existing literature is provided in Chapter 2). Finally, the research objective, questions and scope of the thesis are presented.

1.1 The importance of services

Over the years the academic research community has formulated ideas about a stronger focus of services in the economy (Quinn et al. 1990; Chesbrough & Spohrer 2006). Typically this idea is based on the growth of service activity across industries in developed economies. The economic activities in developed countries have shifted since the advent of the industrial revolution from predominantly agriculture, mining and fishing (primary sector), through manufacturing (secondary sector), to the present day where services (tertiary sector) dominate the economy. Service industries are here understood as wholesale and retail trade, restaurants and hotels, transport, storage and communications, finance, insurance, real estate and business services, and community, social and personal services (ILO 2007). Even though the service sector dominates

in developed economies, it continues to grow, whilst jobs in manufacturing and agriculture are diminishing (see Figure 1.2). A corresponding picture can be drawn for the economic value (measured in gross domestic product) of services. Furthermore, in many industrialised nations, services now account for more than 30 per cent of total industrial R&D expenditures (Salter & Tether 2006). It is therefore fair to say that our current economy is already a service economy.

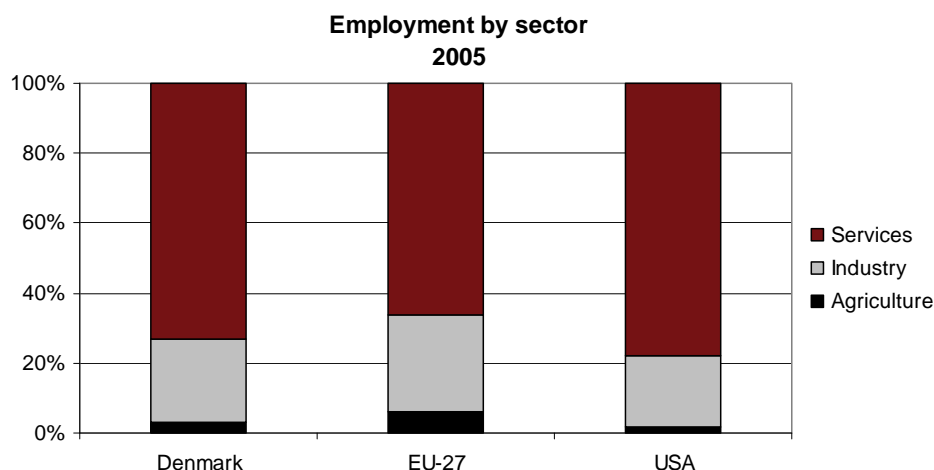


Figure 1.2 The majority of people in developed countries are employed in the service sector (ILO 2007).

1.2 Services in manufacturing

In a renowned article in Harvard Business Review, Levitt (1972) claims that *“Everybody is in service”* and argues that the taxonomy used for services is outdated and should include all kinds of services – including product-related services supplied by manufacturers. Similarly from a service marketing perspective, Grönroos (2000) takes the standpoint that it does not make sense to determine whether customers buy products or services. What they actually buy are the benefits that products and services provide them with. From this perspective, all companies can be said to offer services, even traditional manufacturing firms. In some industries, e.g. aircraft, telecommunications, medical equipment, etc., it has been the norm for many years to deliver integrated product and service solutions (see Table 1.2). Today services are a fast growing part of business for many manufacturing companies (Chesbrough & Spohrer 2006; Koudal 2006).

Traditionally in academia, services have been perceived as a niche field while the application of marketing, management and engineering has been focused on products (Grönroos 2000; Rust & Mui 2006). Based on this, the multinational computer technology and IT consulting corporation, IBM, has taken the initiative to establish and promote a new academic discipline called *Service Science* (IfM & IBM 2007), to emphasise the importance of the educational, business and policy making aspects of services in our society.

Global industry	Share of service and parts business in overall sales	
	Average (percent)	Top 90 th Percentile (percent)
Aerospace and defence	47%	More than 50%
Automotive and commercial vehicles	37%	More than 50%
Diversified manufacturing and industrial products	20%	More than 50%
High technology and telecommunications equipment	19%	More than 50%
Life sciences/medical devices	21%	More than 50%
All companies	26%	More than 50%

Table 1.2 Service accounts for a large part of the business of many manufacturing industries (after Koudal 2006).

Moreover, it has even been suggested that business is already progressing into the next stage of economic value: experiences (Pine & Gilmore 1998), which further advocates the need to understand the role of services in manufacturing (see Table 1.3).

Economic Offering	Commodities	Goods	Services	Experiences
Economy	Agrarian	Industrial	Service	Experience
Economic function	Extract	Make	Deliver	Stage
Nature of offering	Fungible	Tangible	Intangible	Memorable
Key attribute	Natural	Standardised	Customised	Personal
Method of supply	Stored in bulk	Inventoried after production	Delivered on demand	Revealed over a duration
Seller	Trader	Manufacturer	Provider	Stager
Buyer	Market	User	Client	Guest
Factors of demand	Characteristics	Features	Benefits	Sensations

Table 1.3 The distinction of economic value of commodities, goods (products), services and experiences (after Pine & Gilmore 1998).

From an economic perspective the importance of a service-orientation in manufacturing alone would be sufficient to merit further study in the area, but the shift from a product to a service perspective seems to hold a potential for two other opportunities, that are very relevant for design; value creation and the environmental impact of products (Manzini & Vezzoli 2002; Tukker & Tischner 2006). A common theme for these aspects of design is the expansion of understanding the task of design as something that is not just related to the product itself, but relates to the whole product life, its various systems, stakeholders and the activities and effects that emerge from this (Olesen 1992; Olesen et al. 1996).

The dominant logic in manufacturing has been focused on tangible resources where value is considered to be embedded in the physical artefact and determined by discrete transactions. This logic is challenged as being a narrow and limiting perspective on value, as it overlooks the use activities, and interactions and relations between the stakeholders surrounding the product (Vargo & Lusch 2004). A service perspective in manufacturing will enable a broader and more comprehensive view to value as services are considered activities that include the customer's perspective and the use value of products (Grönroos 2000). Here we see the possibility of better understanding customers and product use through services.

1.3 Product/service-systems

There is nothing new in the fact that companies offer products and services together. Every product involves services such as sales, delivery, maintenance and repair services (Grönroos 2000), and every service involves physical products in order to provide the benefit (Shostack 1982; Bitner 1990). Yet, traditionally in most companies the development of services and products has been separated - both in terms of process and of organisation. This has entailed that the potential for products and services to mutually support each other has not been properly articulated.

1.3.1 Sustainable development

The concept of *Product/Service-Systems (PSS)* can be traced back to prior environmental concerns of how the world's economy is currently coupled with material and energy consumption. The possibility that economic growth could still be achieved without compromising the Earth's natural environment, was widely recognised under the term *sustainable development* in the 1987 Brundtland report (Brundtland 1987).

One of the strategies to decouple material and energy consumption with economic growth is to substitute a material product with an immaterial way of fulfilling the same need or function, i.e. a service (Mulder 2006). This approach is called '*dematerialisation*', where the aim is to fulfil a need by consuming significantly less material and energy. Stahel and Reday (1976/1981) were among the first to consider the potential to develop a more labour-intensive and less energy-intensive economy through product-life extension. Compared with manufacturing, this constitutes a substitution of manpower for energy, and decentralised workshops instead of centralised factories (see Table 1.4). Stahel (1997) uses both the terms '*service economy*' and '*functional economy*' synonymously to describe this approach to sustainability.

Traditionally, approaches to minimising environmental impact have focused on the life cycle stages of production and supply, through pollution control (so-called *end-of-pipe approaches*), and *cleaner production*

technologies (Manzini & Vezzoli 2002). This later expanded to also focus on cleaner products throughout their entire life cycles. Stahel's (1997) approach to sustainability included the consumption and demand of products. He identified four main strategies within the systems approach that contribute to more sustainable solutions:

- *Sufficiency solutions* (demand side).
- *Systems solutions* – reducing volume and speed of resource flow (supply and demand side efficiency).
- *More intensive use of goods* reducing the speed of the resource flow (supply and demand side efficiency).
- *Longer use of goods* reducing the speed of the resource flow (supply and demand side efficiency).

Sale of a product (industrial economy)	Sale of a performance (service economy)
The object of the sale is a product.	The object of the sale is performance, customer satisfaction, the result.
The seller is liable for the manufacturing quality (defects).	The seller is liable for the quality of the performance (usefulness).
Payment is due for and at the transfer of the property rights (an as-is, where-is principle).	Payment is due pro rata if and when the performance is delivered (a no-fun, no money principle).
The work can be produced centrally or globally (production); products can be stored, re-sold, exchanged.	The work has to be produced <i>in situ</i> (service), around the clock, no storage or exchange is possible.
Property rights and liability are transferred to the buyer.	Property rights and liability remain with the fleet manager.
Advantages for the buyer: <ul style="list-style-type: none"> - Right to a possible increase in value - Status value as when buying performance 	Advantages for the user: <ul style="list-style-type: none"> - High flexibility in utilisation - Little own knowledge necessary - Cost guarantee per unit of performance - Zero risk - Status symbol as when buying product
Disadvantages for the buyer: <ul style="list-style-type: none"> - Zero flexibility in utilisation - Own knowledge necessary (driver's license) - No cost guarantee - Full risk for operation and disposal 	Disadvantages for the user: <ul style="list-style-type: none"> - No right to a possible increase in value
Marketing strategy = publicity, sponsoring	Marketing strategy = customer service
Central notion of value: high short-term exchange value at the point of sale	Central notion of value: constant utilisation value over long-term utilisation period

Table 1.4 The differences between selling performance and selling products (after Stahel 2001).

Environmental effects of products occur in all of a product's life phases (Wenzel et al. 1997), but traditionally manufacturing companies are responsible for the production of their products, but only involved to a limited degree in the use phases. For many (especially energy consuming) products, the largest environmental effects occur during the use phase (see Figure 1.3). During the United Nations Conference on

Environment and Development (UNCED) in Rio de Janeiro in 1992, sustainable production and consumption emerged as a key issue on the sustainable development agenda (UN 1992).

The World Business Council for Sustainable Development (WBCSD) acknowledged that a *total life cycle perspective* must be considered, and identified four areas where companies could combine economic and environmental performance (WBCSD 2001):

- **Dematerialisation** by developing ways of substituting material flows with knowledge flows.
- **Closing production loops** by ensuring outputs and waste that can be used as resources in the same or other production systems.
- **Service extension** by developing customised responses to customer needs through leasing.
- **Functional extension** by manufacturing products with new and enhanced functionality and selling services to enhance the functional value of those products.

PSS attempts to incorporate all of these areas as it provides companies with the possibility to respond to customer needs efficiently and sufficiently. In many cases, it is not the product and its technology that is the problem, but the (mis)use and (over)consumption patterns which emerge when the product is subject to users in practice (see Figure 1.3).

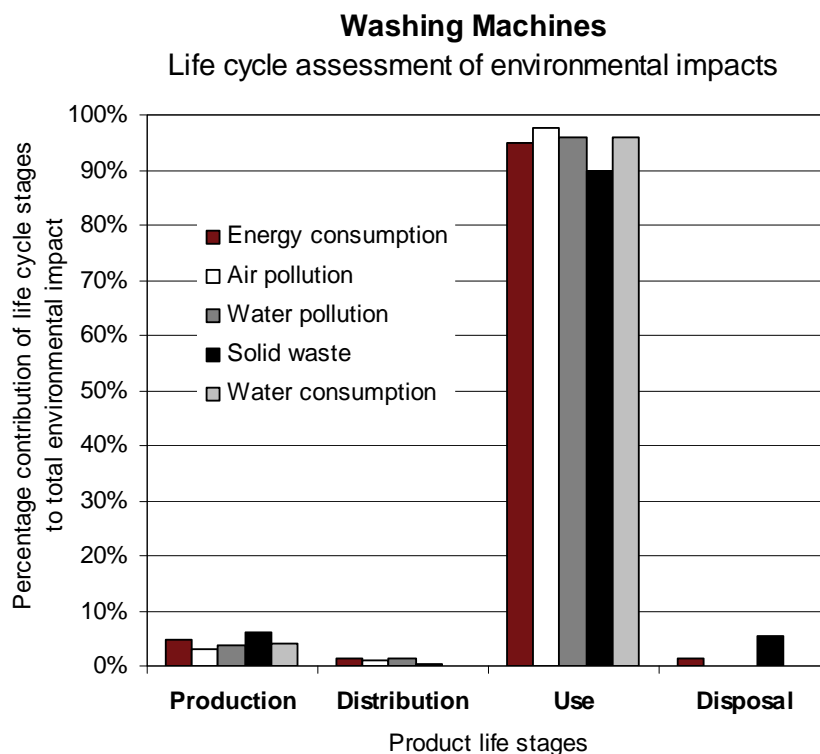


Figure 1.3 For most energy consuming products the environmental impacts are greatest during the use phase. This is typically the life phase where manufacturers have least influence and responsibility (adapted from (PA Consulting 1991) and (UK Ecolabelling Board 1992)).

1.3.2 Motivation for service-orientation

Increasing global competition and shorter product development cycles have been putting steady pressure on traditional manufacturing companies in recent years. Products are designed, manufactured and distributed in greater quantities at lower costs, faster and of better quality than ever before. As low labour cost countries have increased their industrial capabilities, competing has proven difficult for manufacturers in developed countries. Competitors are never far behind on today's markets. Profit margins on the sale of products, particularly those of mature technology and in saturated markets, are diminishing. Here companies are already experiencing difficulties in differentiating their products, with respect to price, function and design. This situation casts doubts on whether manufacturing firms' traditional business approaches will be profitable in the future. Discouraged by strategies that only seek to decrease costs, companies are looking for new areas for growth.

There are many reasons why manufacturers are becoming interested in service-orientation (Mathieu 2001a; Ölundh & Ritzén 2003; Glueck et al. 2006; Reinartz & Ulaga 2008) . To begin with they may be spurred by the following threats:

- *Commoditisation of products* – even high tech products – leading to fierce price competition and diminishing profit margins
- *Saturation of markets* and a *high installed base*, which limits the amount of new product sales
- *Greater responsibility of products* as quality issues that emerge late in the product life can cost companies money as well as reputation
- *Proliferation of new products* which increases competition and shortens sales cycles
- *Financial crises* that restrain new product purchases

Under these conditions many manufacturers are finding it hard to be profitable and therefore looking for other areas they can grow the business. Here service-orientation seems promising as it can offer the following potential business opportunities:

- *Higher profit margins in services* compared to products (see Figure 1.4);
- Increased product sales by *differentiating products with services*
- The *realisation of new product functionality and/or increased value* through services
- The *continued outsourcing of operations* as customers just want to focus on their core activities
- *Reducing downtime and failure of equipment* critical to customers' activities

- Demand for *simple and easy operation of complex systems*
- Strengthening *long term customer relationships* that result in loyal customers and repeated sales
- An extra and/or more *stable source of revenue* after product sales
- Reducing risks with the *introduction of new technology* improves *new product adoption*
- Business and/or product complexity requires *specific competencies and capabilities*

In the business literature, better environmental performance is rarely listed as a driver for service orientation (Ölundh & Ritzén 2003), although companies often discover subsequently that the environmental benefits of services are important selling points that can be used in sales and marketing.

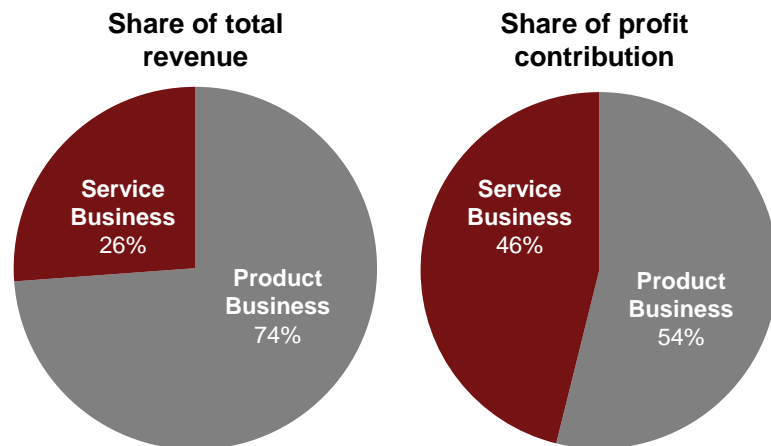


Figure 1.4 On average service operations are more profitable than the overall profitability of other business units according to a survey amongst manufacturing firms done by Deloitte (after Glueck et al. 2006).

In spite of these opportunities, many manufacturers struggle to successfully exploit the financial potential of services (Gebauer et al. 2005). This may simply be because companies tend to overlook the value of services (Oliva & Kallenberg 2003) and give them away for free (Anderson & Narus 1995). Or as in some cases, services are even perceived as a threat that restrict product sales (Reinartz & Ulaga 2008).

Despite the many opportunities, not all manufacturing companies should adopt service-oriented strategies. There are certain conditions and contexts that make service-orientation more opportune than others. Wise and Baumgartner (1999) list a number of factors that would indicate the potential for service-oriented business downstream:

- Attractiveness of *downstream opportunity*, measured in e.g.:
 - Ratio of installed base to new product sales is greater than 15 to 1 (i.e. there are more than 15 products in use for each new product sold)

- Total life cost of the product is over four times the initial purchase price
- The downstream margin is over 5% greater than the product margin of the purchase price.
- Importance of *customer relationships*, given by e.g.:
 - Products are considered as commodities (minimal differentiation) on the market
 - Market share of the top five customers are over 40%
 - Share of total profit earned from top 20% of customers are over 50%
- Power of *distribution channel*, described as e.g.:
 - Distribution and selling costs is over 25% of the product price
 - Degree of channel concentration - the market share of the top five distributors is over 40%
 - Degree of channel innovation is very dynamic

According to Wise and Baumgartner, these metrics allow companies to assess the attractiveness of service-oriented business and provide an idea of the size of the business opportunity.

1.3.3 The state of services in manufacturing firms

Although services and service-orientation seem to offer considerable potential for manufacturing firms this is not very apparent to most companies (Glueck et al. 2006). Currently, services are often cached or overlooked in manufacturing firms (Koudal 2006). They exist and are necessary for business but are not considered strategically. This results in service development only being performed ad hoc and typically in a responsive manner to insistent clients (see Figure 1.5). Furthermore there is no visibility to the value and performance of services. Even in companies where services do contribute to a sizeable amount of the organisation's revenue, they remain an afterthought in relation to the product-oriented development process.

The opportunities for more sustainable business are currently very rarely linked to service-orientation in companies (COWI 2008). Although *Ecodesign* (design methods that seek to minimise the environmental impacts of products) is becoming more common in companies, PSS approaches have only been applied to a limited extent. This could be partly due to services not generating much attention in general, but is also related to the fact that PSS approaches often entail major changes to existing business and modes of operation.

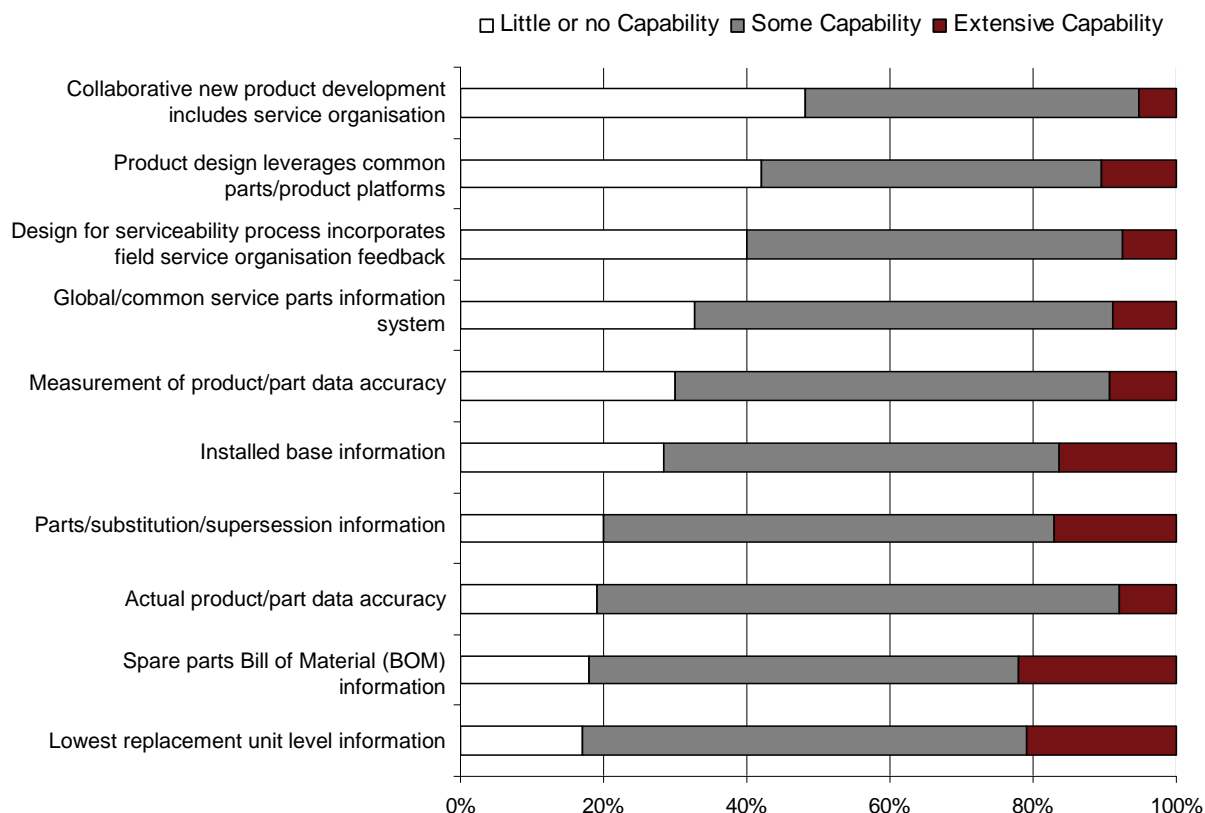


Figure 1.5 Only a few manufacturing companies have managed to effectively integrate service-orientation approaches into their design and development activities (Koudal 2006).

There exist several examples of companies that have succeeded in providing integrated services with products: IBM, Rolls Royce, Xerox, Interface, JCDcaux, Danfoss, Alstom, Ericsson, Thales, Cable & Wireless, WS Atkins (Davies et al. 2006). Although PSS approaches have shown that they can help manufacturers be competitive in today's global market, wide industry adoption has yet to be seen (Baines et al. 2007). Several projects have investigated the drivers, barriers and opportunities to adopt PSS approaches in both business-to-business and business-to-consumer contexts (Mont 2004; Wong 2004), but the understanding of how these companies have made this move is still not clear (Davies et al. 2006). Oliva and Kallenberg (2003) were among the first to focus on how manufacturing firms made the transition, but there is still a lack of evidence in the systematic and normative approaches to service-oriented product development (Gebauer et al. 2008). There is still a need to develop models, methods and theories for PSS design and development (Mont 2004; Baines et al. 2007).

1.3.4 Research in PSS

In the previous section of this chapter the relevance and importance for understanding service-oriented development in manufacturing firms was established. In the following, a brief background on the knowledge within research is provided and the focus of this thesis is determined. A deeper discussion of the literature related to PSS can be found in the literature review in Chapter 2.

Research in PSS from an environmental perspective

In the late 1990s several researchers dwelled upon the ideas of service-orientation and dematerialisation and proposed methods and tools to encourage companies to follow these product life strategies. Using the term '*strategic design for sustainability*', Manzini (1999) applied a *design perspective* to how companies could move from a traditional product-oriented business model to a new product-service one. Jansen and Vergragt (1997) considered how sustainable product systems need to cross company boundaries and include all stakeholders in the process. Goedkoop et al. (1999) analysed how PSS could be analysed environmentally and economically. Between 2002 and 2004 within EU's 5th Framework Programme, a research network called *SusProNet* (*Sustainable Product Development Network*) investigated the possibilities of PSS approaches and developed methods and tools for the development of PSS (Tukker & Tischner 2006).

Research in PSS from a business perspective

In parallel, but completely independent of the environmentally focused community, researchers in the business literature have pointed at the economic potential for manufacturers to move into services (Canton 1984; Potts 1988; Vandermerwe & Rada 1988). Wise and Baumgartner (1999) demonstrated on pure economic conditions, that for many manufacturing firms' products, life supporting services represented the greatest source of new revenue and profit (see Figure 1.6). Many researchers in business literature have discussed how manufacturing firms can manage the shift into services simply because it makes good business sense (Canton 1988; Vandermerwe et al. 1989; Oliva & Kallenberg 2003). It is only recently that these two streams of environmentally and economically motivated research literature have been integrated (Tukker & Tischner 2006).

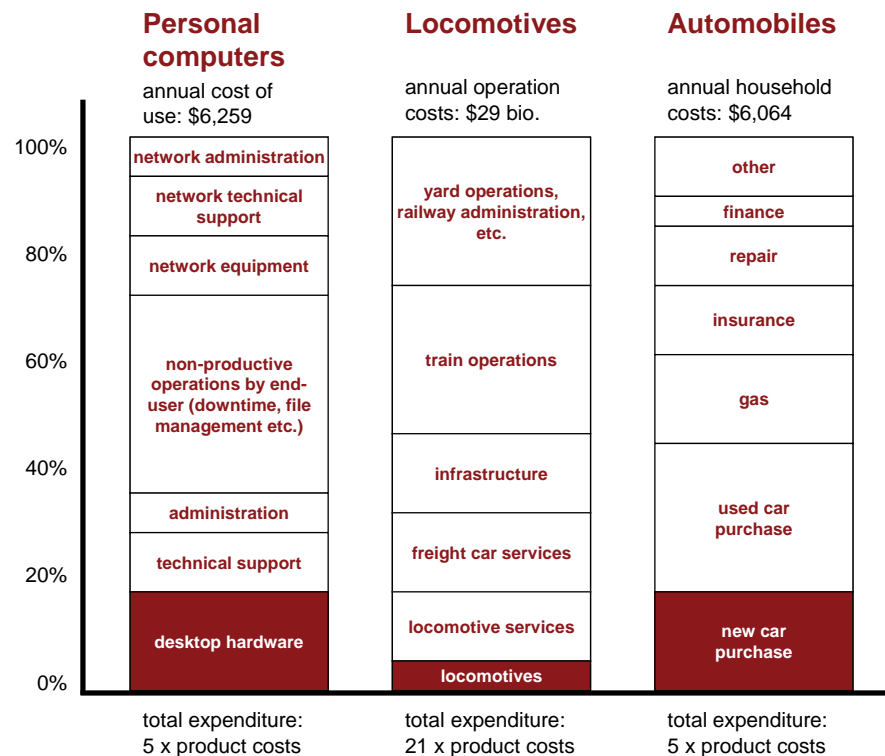


Figure 1.6 The purchase cost of the product only accounts for a fraction of the overall revenues. Providing services throughout the entire product life cycle has a potential for greater revenues and profits for manufacturing firms (after Wise & Baumgartner 1999).

Current status of research in PSS

Over the past decade several research projects have investigated PSS approaches from various perspectives. The first studies focused on the economic and environmental implications of products offered as services (Goedkoop et al. 1999; White 1999; Behrendt et al. 2003). These case-based studies were mainly aimed at promoting PSS approaches in industry and informing policy makers (Zaring et al. 2001). Soon after, the majority of research projects focused on methods, methodologies and tools for the design and development of PSS (Brezet et al. 2001; Tomiyama 2005; Tukker & Tischner 2006). Although a wide range of methods and tools were proposed, the academic rigour and research standard has been questioned (Mont & Tukker 2006; Tukker & Tischner 2006). The methodologies were typically developed in projects removed from manufacturing firms' actual development context or completely independent of industry. The results of these projects have yet to be verified (Baines et al. 2007).

A consequence of PSS approaches is the need to address the greater complexities of product planning and product development activities, such as an extended stakeholder gallery; increased product liability; closer contact to end-user; wider palette of products; and the opportunity and necessity to re-consider core business (McAloone & Andreasen 2002). Currently, literature is sparse on the management, organisation, coordination and integration of development activities of

PSS (Johnstone et al. 2008). At the same time companies in service industries would seem to benefit from the systematic approaches in Engineering Design and Product Development (Bowen et al. 1989; Bitran & Pedrosa 1998; Hollins 2006). Parallel with manufacturing firms changing to become more service-oriented (*'servitisation'*), there seems to be an opposite move with service firms changing to become more product-oriented (*'productisation'*) (Baines et al. 2007). Service firms are being pushed to innovate and increase productivity in their operations (Nallicheri & Bailey 2004) which lags far behind the performance of manufacturing firms. Traditionally, the focus of design disciplines has been on the 'product' as a tangible technical (and often specifically mechanical) artefact. Methods and approaches have been developed to support product design, and have not considered that services also need to be designed. It would be relevant for these disciplines to expand their usefulness and assert themselves in services. The shift in perspective from the design of physical products to intangible services also represents a challenge for designers (Morelli 2003). Here, their role and competencies need to be reconsidered with service-orientation.

1.3.5 PSS as merely a possibility for sustainability

The dominant paradigm in most manufacturing companies is to sell as many products as can be produced. This has resulted in mass-consumption and depletion of the planet's limited natural resources as well as severe impacts on its eco-system. PSS approaches aim to meet the needs of customers by providing a service instead of a physical product per se. This service-orientation is thought to be less material and energy demanding. With PSS, the ownership of the product is typically retained by the manufacturer, which is thereby incentivised to optimise the utility of its physical assets. This can be done by prolonging the product's useful life, increasing its use so more customers may benefit from it, or ensuring that the material components are never lost at their end-of-life, but always kept within the material flows of the industrial system.

Although PSS approaches have risen out of environmental concern, PSS approaches do not guarantee improved environmental performance by themselves (Tukker & Tischner 2006). Services may seem less material demanding but are by no means free of environmental effects, as all services include products, and their delivery involves the consumption of materials and energy (Graedel 2003). Furthermore, it has been observed that some PSS can result in even worse environmental performance globally as an increase in environmental efficiency of individual products and services, may actually encourage even greater consumption and usage (Manzini & Vezzoli 2002). These unintended side effects of introducing new products and services are called '*rebound effects*' and are determined by our consumption patterns, behaviour and affluence (Tukker & Tischner 2006).

Nonetheless, it is generally recognised that due to the system's perspective, where products and their effects are considered throughout their entire life cycle, PSS approaches do hold a potential for more efficient use of natural resources and need satisfaction. PSS approaches attempt to address both the supply and demand side of products and services. Currently, the United Nations Environmental Programme (UNEP) actively promotes the concept of PSS as it sees it as a possibility for more sustainable production and consumption (Manzini & Vezzoli 2002).

Term	Definitions and narrative identifications	Authors
Product-Service	<i>"...an integrated whole of mutually dependent products and services that, to be designed, produced and delivered, require a new corporate culture and organization."</i>	(Manzini 1999)
Product Service system	<i>"A Product Service system (PS system) is a marketable set of products and services capable of jointly fulfilling a user's need. The PS system is provided by either a single company or by an alliance of companies. It can enclose products (or just one) plus additional services. It can enclose a service plus an additional product. And product and service can be equally important for the function fulfilment."</i>	(Goedkoop et al. 1999)
Product-Service System	<i>"A Product-Service System can be defined as the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands."</i>	(Manzini & Vezzoli 2002)
Product Service System	<p><i>"A PSS has the following characteristics:</i></p> <ul style="list-style-type: none"> <i>– In the time domain it is a sequence of multiple, interrelated life phases and activities throughout the product's service time, i.e. the period where it is utilised in accordance with its planned purpose.</i> <i>– In the artefact system domain, it is a set of multiple, interrelated systems, between which the product life phase system of use is the predominant, but where other systems (the producer's maintenance system, the overall system related to the product, the supply of input to the product, etc.) can also be of importance.</i> <i>– In the value domain it is a set of multiple stakeholders' values, determining the utilisation and reactions to the artefact systems and activity systems effects and determining how seriously the side effects are regarded."</i> 	(McAloone & Andreasen 2002)
Product-service combinations	<i>"Product-service combinations (or eco-services) are those intangible service components that partially or completely substitute for tangible components, resulting in a positive effect on the environment."</i>	(Behrendt et al. 2003)
Product Service System	<i>"Product Service Systems (PSS) may be defined as a solution offered for sale that involves both a product and a service element, to deliver the required functionality."</i>	(Wong 2004)
Product-Service Systems	<i>"A product-service system is a system of products, services, networks of actors and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and has a lower environmental impact than traditional business models."</i>	(Mont 2004)
Product-service	<i>"Product-service (PS): a mix of tangible products and intangible service designed and combined so that they are jointly capable of fulfilling final customer needs."</i>	(Tukker & Tischner 2006)
Product-service system	<i>"Product-service system (PSS): the product service including the network, technological infrastructure and governance structure needed to 'produces' a product-service."</i>	
Product-Service System	<i>"A PSS is an integrated product and service offering that delivers value in use. A PSS offers the opportunity to decouple economic success from material consumption and hence reduce the environmental impact of economic activity. The PSS logic is premised on utilizing the knowledge of the designer-manufacturer to both increase value as an output and decrease material and other costs as an input to a system."</i>	(Baines et al. 2007)

Table 1.5 An overview of various definitions of PSS.

1.3.6 How PSS is understood in this thesis

No commonly accepted definition of Product/Service-Systems currently exists. As it is a cross-field of multiple disciplines, until now, each researcher has put a different emphasis on the priorities of PSS (see Table 1.5 for a list of the major PSS research projects and their emphases). One major difference in the definitions is whether PSS solutions should lead to a lower environmental impact than existing business models. In terms of design and developing PSS, this must be seen as more of an expression of intent than a definition, and the particular focus on environmental benefits relates here to the previously mentioned history of PSS as a phenomenon.

The terms and definitions in Table 1.5 mainly refer to PSS as a value proposition offered to customers and describes PSS as the result of a design process. At the same time PSS also refers to a business model based on service-oriented strategies. When these different perspectives of PSS are not clearly distinguished from each other, it is difficult to explain what PSS are and how they can be adopted by manufacturers. In this thesis, PSS is understood on three levels, that the author finds useful to operate with:

1. a PSS solution as *a system of integrated products and services* that companies develop and deliver in order to fulfil a need with their customers.
2. PSS development as *the integrated design and development activities* that result in PSS solutions.
3. PSS approaches as *business strategies that coordinate PSS development* and allow manufacturers to become more service-oriented.

These three different perspectives of PSS research will be further investigated in the literature review in Chapter 2.

1.4 Research aim, objectives and questions

Building upon the research in Engineering Design and Product Development, this PhD project emphasises the synthesis-oriented aspects of PSS development. The aim of the research, like in most Engineering Design research, is to improve the development processes in companies. PSS is a fairly new research field, where most of the research is concerned with the economic and environmental possibilities and potentials of such systems. But, limited work has been carried out on the synthesis and design-oriented aspects of this innovation strategy.

1.4.1 Research aim

So far not much research has been completed in establishing PSS approaches in the context of manufacturing firms and their existing business. The shift to new business strategies is not a trivial undertaking

and firms face many barriers and challenges when implementing service-oriented strategies. *This PhD project aims to provide industry with a better understanding of how products and services may be designed and developed in a manner that is both competitive and sustainable in economic, social and environmental terms.* In addition this project aims to expand the field of Engineering Design and Product Development to also include the design and development of services.

1.4.2 Research objectives

The objective of this research is to gain insight into the design and development of PSS, and suggest how more systematic creation of alternative PSS solutions may be performed in manufacturing companies. The objective of this research may be therefore summed up as:

- A. *to establish a theoretical foundation* for the systematic and methodological approach to PSS design; and,
- B. *to propose service-oriented development strategies, methods and techniques for manufacturing firms* that wish to adopt PSS approaches.

1.4.3 Research questions

This thesis is guided by three research questions that investigate the design and development aspects of PSS approaches in manufacturing firms. The first question relates to establishing a theoretical foundation for PSS design. This leads to the second question, which deals with how PSS solutions can be pragmatically structured and introduced to manufacturing firms. The third and last question deals with the grounding of PSS within the context of manufacturing firms.

Q1: Compared to traditional product development, how can PSS be understood?

In literature and practice there seems to be a clear understanding of what a product is and how it is developed. This is not the case with PSS. Based on the established and accepted theories in Engineering Design and Product Development, this PhD project scrutinises the nature of PSS in order to establish a theoretical foundation for the synthesis of PSS that will allow systematic methods to be developed. This part of the research is conceptual and, in essence, a study of the application of a theoretical framework (Engineering Design) to a new domain (PSS).

Q2: How may PSS be conceptualised?

The interest in PSS is not merely about how manufacturing firms develop services. It is rather how products and services can be integrated to be competitive and more sustainable. A product concept describes all the essential aspects of a product, combining both need/market considerations and design/realisation considerations (Hansen & Andreasen 2003). In order to systematically realise the

sustainability potential of PSS, the essential aspects of the PSS solutions have to be clarified during conceptualisation. This thesis sets out to define the conceptual elements of PSS in order to support the early phases of PSS development.

Q3: How may PSS be developed in manufacturing firms?

PSS approaches are currently not well adopted in manufacturing firms. This research question deals with how manufacturing companies may design and develop successful PSS seen in relation to market conditions, organisation and strategy. Here empirical observations of the design and development activities of products and services in companies serve as a basis for a model for PSS development.

1.4.4 Research object and scope

This PhD project focuses on how integrated products and services are developed in the context of manufacturing firms. Manufacturing is a broad term covering many different industry sectors. In this thesis, manufacturing companies are understood as any company that has mainly based their business on the development, production and sales of products, i.e. technical, physical artefacts, e.g. cars, chairs, computers, etc. The unit of analysis of this research restricts itself to the level of a strategic business unit's organisation and how it is bound together by its network of suppliers, partners and customers.

The phenomenon that is studied in this research is the *design and development activities* in companies. These do not only occur in a single department or division (i.e. R&D) of the company, but happen anywhere in the company at many different levels from project level to company strategy level. For many companies, PSS approaches represent a change of business model and strategy, which means that PSS offerings are not necessarily developed in the product development department but pertain to business development.

PSS is an academically constructed term without clear definitions of what is or is not a PSS. As shall be seen in the next chapter it is not even clear what is the distinction between a 'product' or a 'service,' as they can both be related to each other. The underpinning of this thesis is that products and services are defined in relation to the benefit they provide (see section 2.2 for a deeper discussion). In this research the distinction is made between what is '*product-oriented*' (aimed at the physical artefact where value is seen as embedded with the artefact) and what is '*service-oriented*' (aimed at the user activity where value is derived from the use and interaction with the artefact). Although indiscrete, it is however possible to identify characteristics that are either '*more product-oriented*' or '*more service-oriented*.' The research object is therefore "*the design and development activities in a strategic business unit of a manufacturing company that lead to the employment of PSS approaches.*"

1.4.5 Key terms

The terms used in this thesis are sometimes given different meanings in literature and industrial practice. As Chapter 2 investigates provides a deeper discussion of these terms, the following only offers a general reference for how the key terms in this thesis are understood.

Customer

Although it is possible to clearly distinguish between *customers* (who pay for products/services) and *users* (who operate or use products/receive services), the term *customer* in this thesis encompasses both roles, unless it is clearly specified. Besides *user*, the term is also synonymous with *client*, *consumer*, *buyer* and *purchaser*. A customer may be an individual, a group, an organisation or another company regardless of the type of business, e.g. business-to-business, business-to-consumer, business-to-government, etc.

Company

A *company* in this thesis is an organisation of people that engage in activities with business objectives. *Companies create and provide* products, services or systems (or any combination of them all) to customers in order to generate business. Both *manufacturers* and *service providers* are companies. Companies can also be *customers* themselves if they purchase products or services from other companies (*suppliers*). The roles of *company* (seller) and *customer* (buyer) are defined by their relationship in a value chain. Two companies that work closely together and mutually benefit from the collaboration are called *partners*.

Actor

An actor can be an individual, group or organisation that is *actively engaged in the business between a company and a customer*. The company and customer are of course the main actors, but many more actors are involved in the process, e.g. public authorities, distributors, employees, etc. including those upstream (supply side) and downstream (demand side) of the main interaction. Actors are a subset of *stakeholders* (everybody that has an interest (or stake) in the business between a company and a customer), where actors are the stakeholders that actively influence the business process. In *Actor Network Theory* (Latour 1991) an actor can also be non-human, e.g. an artefact, a technology, an event, etc., but in this thesis only human actors are considered.

Design and development

The word '*design*' can be used in multiple contexts and leads to different understandings. First of all design is the general field of study of this thesis. It covers all forms of *design activity*, e.g. *industrial design*, *engineering design*, *interaction design*, etc. Design is also an *object*, e.g. a product, a service, a system, etc. that is the result of a design process. The *design process* covers the activity of designing, e.g. identifying needs,

generating ideas, evaluating concepts, detailing designs, planning production, etc. *Designers* are the people (regardless if they are trained professionally or not) involved with designing. '*Development*' is often used synonymously with design (also in this thesis), but with the subtle difference that '*design*' relates more to the design object, and '*development*' relates more to the organisation of the design activities covering the whole value creation process from need to business (Marxt & Hacklin 2005). In this thesis both the terms *design* and *development* are used in parallel as this is also common practice in literature.

Product

A *product* is anything that *results from a process*, is offered on the market and whose ownership can be transferred. However, in this thesis a '*product*' is restricted to mean physical objects or goods. This is done in order to contrast '*service*' and follows the traditional understanding in Engineering Design. Although not a physical object as such, software programmes are also considered products, as they can be related to physical entities, and are therefore also considered as products in this thesis.

Service

Yet another word with several connotations is '*service*'. To start with, services describe a *sector of the economy* or industry, e.g. transport, retail, education, tourism, finance, healthcare, communications, etc. In general, a service is an *activity or deed* performed by one actor (a *company*) and offered to another (a *customer*). Whilst products are seen as *artefact systems*, services are *activity systems*. In this thesis only services that are performed in a business context are considered. Although a service is presented as non-physical and the diametrical opposite to a product, the difference is not that clear cut (as shall be seen in the following chapter, section 2.3). In engineering and manufacturing literature '*service*' is often referred to as the *maintenance of products*, but in this thesis services encompasses many more types of activities, e.g. consulting, designing, financing, operating, etc.

System

A *system* is defined as an arrangement of *elements*, which influence each other through *relations* and which can be delimited from their surroundings by a *system boundary* (Blanchard & Fabrycky 1998). A system has a structure which denotes its elements and their relations. Elements of a system may themselves be systems, and every system may be part of a larger system. Products are *technical systems*, whilst services are *process or activity systems*. Specific to this thesis, *product life phase systems* or *service systems* are all the technical systems surrounding the *product* and *actor* that enable the *activity* to happen, e.g. the telecommunications infrastructure for a mobile phone when a user is making a call.

Strategy

A *strategy* is a plan for how to achieve a certain objective whilst employing certain actions or means within a particular context or environment. In this thesis a strategy can relate to a company's overall business plan, but can also be on a lower level related to a functional department, e.g. product development, a project team, or even an individual. A strategy is often detailed in a tactic, which is a specific plan for a strategy. When a strategy and tactics are realised, they become operations. The words approach and process are also used to mean the same thing, with approach being less defined and process being more defined.

Concept

A *concept* in design is a *proposal for a product or service*, which is brought to such a level of concretisation, that allows someone to communicate to others the most important and distinguishing aspects of the product or service and how it will satisfy the customer needs (Hansen & Andreasen 2003). In this thesis concepts are treated as operational descriptions that combine several ideas which together define all the essential aspects of a design object fusing both *need/market considerations* and *design/realisation considerations*. A concept can relate to a product, service or even a business model.

Value

Companies create value by design and *customers judge the value* of products and services. A value can be a *basic belief* that people base their judgement about what is right, good or desirable. This understanding of the term is not considered much in this thesis. Instead, the focus is on the value relating to how one actor can fulfil the needs of another through the provision of products or services. The notion of value is difficult to define completely as it is *subjective, relative and dependent on context*. It is however the very essence of design. *Utility* can be used as a synonym for value, when it is understood as some thing practical, functional and useful. Utility is the predominant perception of value in Engineering Design, although it is just a subset of the term.

Value proposition

A *value proposition* is the comprehensive term to cover products, services or combinations of both. It is anything that is offered to a customer with the intention of generating business. The term an *offering* is synonymous with value proposition.

1.4.6 Related research and other terms

In literature the term '*Product/Service-Systems*' is related and shares common fundamental concepts with other terms such as:

- *Servicizing* (White 1999)
- *Eco-efficient (producer) services* (Brezet et al. 2001; Zaring et al. 2001)
- *Eco-services* (Behrendt et al. 2003)
- *Service Engineering* (Tomiyama 2001; Shimomura & Sakao 2006)
- *Functional Sales* (Mont 2001) (Lindhahl et al. 2006)
- *Functional (total care) Products* (Alonso-Rasgado et al. 2004; Markeset & Kumar 2005)
- *Solution Oriented Partnerships* (Manzini et al. 2004)
- *Life Cycle Management* (Takata et al. 2004)

Also related, but from a pure business driven perspective are the terms:

- *Servitization* (Vandermerwe & Rada 1988)
- *Integrated Solutions* (Brady et al. 2005)
- *Performance Based Logistics* (Kim et al. 2007)
- *Public-Private Partnerships* (PPP)
- *Build-Operate-Transfer* (BOT)
- *Service Level Agreements* (SLA)

Although each concept has different origins and focus, they can all be said to take a life cycle and customer relations perspective on business through the integration of products and services. These concepts will be discussed in further detail in the literature review in Chapter 2. They are presented here to provide the reader with a brief overview of existing related concepts.

1.5 Thesis structure

This thesis has a five part structure (see Figure 1.7). The first two chapters *establish the theoretical foundation* of the research. Chapters 3 and 4 explain how the research in this PhD project was *approached* and describes the background of the *case studies*. Chapters 5, 6 and 7 attempt to address each of the research questions respectively; first through an *analysis of the case studies* and then through *theory building and understanding*. Chapter 8 brings the findings and insights together and *discusses their validity*. Chapter 9 sums up the findings and identifies this thesis' *contribution to knowledge*. Chapter 10 takes a step back and looks at the *implications of the research* and proposes areas worthy of more research.

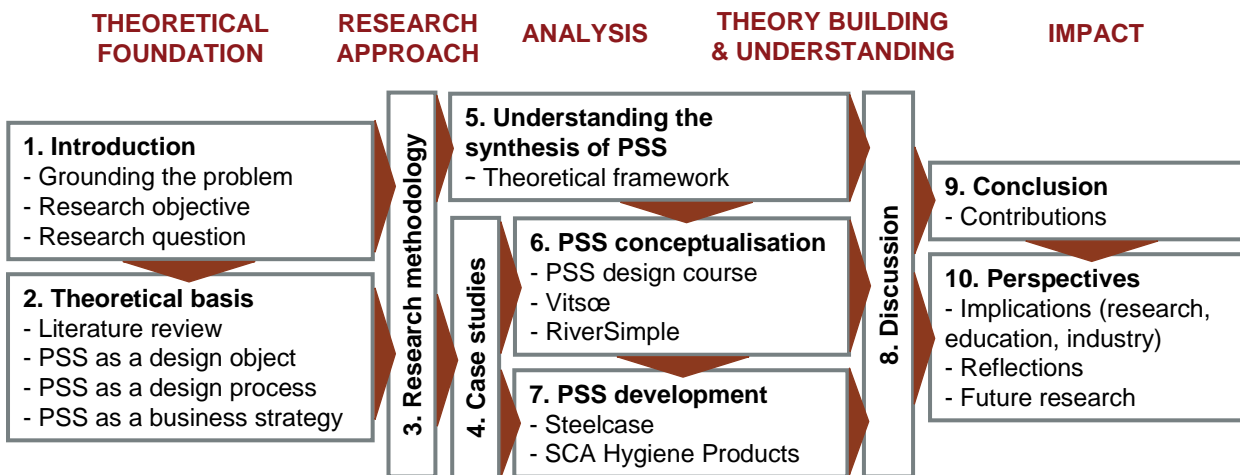


Figure 1.7 The structure of the thesis.

1.6 Summary

This chapter has provided the background and focus of this PhD project. The emergence of services and its relevance to sustainable development has been introduced. Problems related to the increased service-orientation in some manufacturing companies have been identified and gaps in theory established. This has formed the thesis' purpose and central research questions. In summary this chapter has established the following:

- Services are on the increase in the economy and in manufacturing firms.
- Service-orientation has the potential to be a viable strategy for sustainable consumption and production, although this is not always the case.
- Over the past 20 years research within this area has intensified due to both environmental and business drivers.
- The methodologies for the design and development of Product/Service-Systems (PSS) have however not received much attention.
- It is believed that the systematic approaches in Engineering Design and Product Development can be successfully applied to PSS.
- The theories and models in Engineering Design are not directly suited for services.
- The research objective, questions and scope were defined and the key concepts used in this thesis explained.
- Finally the structure of this thesis was presented.

2 Theoretical basis

Chapter 1 introduced the concept of PSS and its emergence in business and academia. This chapter examines the current theoretical knowledge of PSS relevant to design through the three different perspectives of understanding PSS briefly mentioned in the previous chapter. Research in PSS, as well as design in general, is multidisciplinary. This will be seen in the following as the theoretical basis for this thesis is derived from a broad range of research fields.

The objective of this chapter is to provide an overview of the literature that frames the theoretical reference for this thesis. It builds on the traditional product-based Engineering Design and Product Development literature, and then considers the more recent literature on services. Characteristic of the research in services is that it started out in the late 1970s by distinguishing itself from the research on products in order to establish and justify itself as a legitimate research topic, but of late has been more reconciling and now attempts to include both products and services.

In the review of the theories relevant to the design and development of PSS, each contribution is presented in relation to each other in order to provide an understanding of how they attempt to describe and explain the research object of this thesis. The gaps and areas, where the theories are not in agreement or where the theoretical understanding is not convincing, are identified. This is done to draw out a base for the further research in this thesis and the building of theory to support the design and development of PSS in manufacturing firms.

2.1 Theory areas

This thesis deals with the design aspects of PSS. According to Hubka and Eder (1996) design research relates both to the design object and to the design process. The type of research can also be distinguished by its descriptive or prescriptive nature (see Figure 2.1). As mentioned in Chapter 1, both the design object and design process perspectives of PSS will be considered in this thesis. Furthermore, because PSS is seen as an innovation strategy, a third perspective representing the strategic business aspects of PSS development, is related to design:

1. ***PSS as a value proposition*** (design object perspective)
What does an appropriate model for the conceptual design of PSS solutions look like?
2. ***PSS as value creation*** (design process perspective)
What does an appropriate model for the process of PSS development look like?

3. ***PSS as a business strategy*** (strategic management perspective)
What does an appropriate model for the integration of product and service development in relation to a company's business strategy look like?

Each perspective will be described separately according to existing literature in the following sections. This thesis builds upon these perspectives and attempts to form a framework that addresses each of them and how they relate to each other.

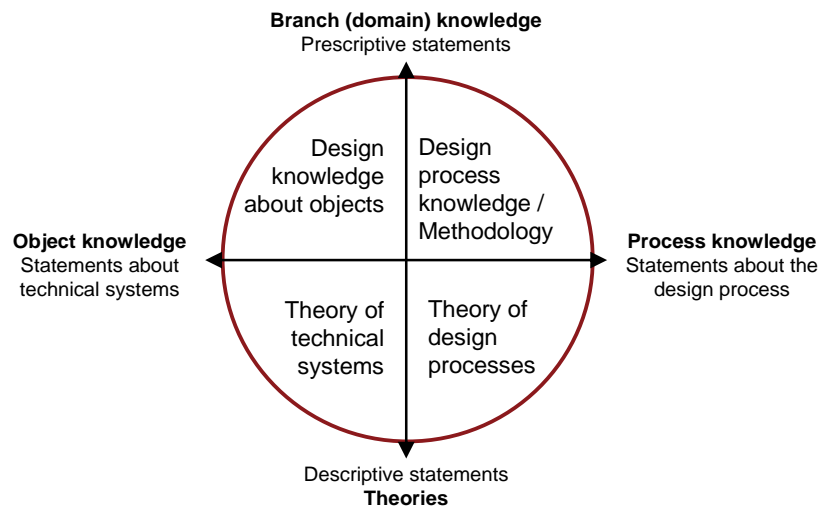


Figure 2.1 The main areas of knowledge in Design Research (after Hubka & Eder 1996).

The structure of the chapter starts first with theories that deal with products and services as design objects that serve as value propositions. Then theories regarding the design and development (synthesis) process are discussed. Finally theories related to business strategies and their relation to development activities in companies. In this thesis the perspective of development activities in manufacturing firms is taken.

2.2 Value propositions at the core of design

Central to the Brundtland report's (1987) definition of sustainable development is the challenge to meet current and future needs. This challenge is synonymous with the purpose of design. Design is responsive to a need and is spurred by the ability to imagine an improvement of a situation. The premise of design is to fulfil needs and thereby create value through the transformation of an existing situation to a more desirable one (Hubka & Eder 1988). Although at the very foundation of design the concepts of needs and value are elusive. Both concepts are subjective, relative, context dependent and constantly change.

A need is a state of felt deprivation by a person or a group of people (Kotler & Armstrong 1994). When customers are asked they often do not

distinguish between needs, wants and demands. Wants are specific objects that might satisfy a need. According to Max-Neef (1992) human needs are universal and *“are the same in all cultures and all historical periods”* whilst wants are shaped by cultural and individual values, e.g. all humans require nourishment but meat is not an option for vegetarians. Value here is understood as *“a basic belief on which [...] judgement is based about what is right, good or desirable”* (Robbins 1996). This represents the first understanding of ‘value’ used in this thesis: a guiding system that determines which objects can act as satisfiers to needs. Demands are wants that are backed with buying power. Here arises the second understanding of ‘value’ used in this thesis: economic worth in which business opportunities arise. Value is seen here as the perceived trade-off between multiple benefits and sacrifices gained through a relationship between a customer and company (Ravald & Gronroos 1996). A third understanding of ‘value’ is usefulness (Nielsen 1993) related to the situation where the product is used. Usefulness is composed of both utility and usability. In all cases it is not possible to give accurate definitions of value but it is possible to define perceptions of value. Many different interpretations of value co-exist. Sometimes it is the (re-)interpretation of value that reveals new value (Kim & Mauborgne 2005). For example, the definition used by Bowers for disruptive innovation is to *“introduce a very different package of attributes from the one mainstream customers historically value”* (Bower & Christensen 1995). See Table 2.1 for examples of disruptive changes in value propositions related to PSS.

Industry	Traditional value proposition	Solution Value Proposition
Truck manufacturing	<i>“We sell and service trucks”</i>	<i>“We can help you reduce your lifecycle transportation costs”</i>
Aerospace components	<i>“We sell high performance fasteners”</i>	<i>“We can reduce your operational costs”</i>
Utilities	<i>“We provide electricity reliably”</i>	<i>“We can help you reduce your total energy costs”</i>
Chemicals	<i>“We sell a wide range of lubricants”</i>	<i>“We can increase your machine performance and up-time”</i>
Pharmaceuticals	<i>“We sell pharmaceuticals”</i>	<i>“We help you better manage your patient base”</i>

Table 2.1 Examples of changes in value propositions (Sharma & Molloy 1999).

Companies aspire to transform value perceptions into value propositions. Value propositions are borne by objects which can be products (physical goods), services, experiences, events, persons, places, properties, organisations, information, or even ideas (Kotler & Keller 2006). These are often bundled together and offered as a whole to customers. The terms *‘offer’* (Johne & Storey 1998), *‘market offering’* (Brännström 2004) and also simply *‘product’* (Kotler & Keller 2006) are used in similar ways to describe value propositions.

For manufacturing firms a value proposition is typically understood as either a product or a service. Products and services are thereby similar in that they both aim to provide benefits and satisfy needs, but the conditions in which they are offered and consumed are different. Whilst products are physical artefacts, services are activities, deeds or processes and interactions (Edvardsson et al. 2005). Both products and services are multi-dimensional creations and therefore have many different aspects applying to different life phases and situations. These aspects again have multiple interpretations depending on the different stakeholders that the product or service interacts with (Bijker 1997). It is the totality of all these dimensions that makes the value proposition. The main point to be made is that it is not only the designers in a company that define this value proposition, but equally the customers, users and society (Tan & McAloone 2006a). Hansen & Andreasen (2002) point out that there is a division between the '*idea in*' and the '*idea with*' a product (or value proposition). The '*idea in*' is the value proposition's make-up (material, technology, infrastructure, etc.), whilst the '*idea with*' is the benefit (with respect to a customer's needs and values). Hansen and Andreasen advocate that designers need to deal with both these aspects of value propositions during design.

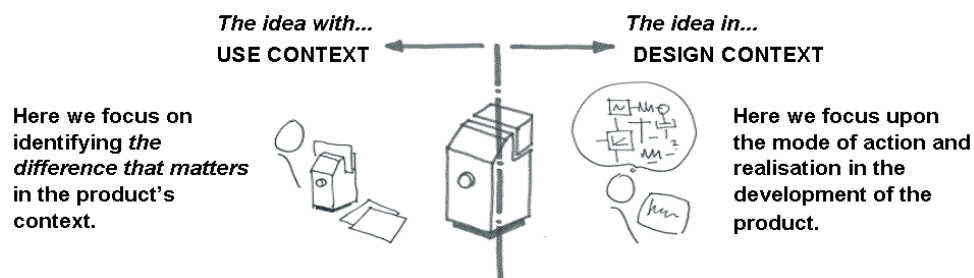


Figure 2.2 The conceptual aspects of a product: left, the '*idea with*' the product – its market oriented use context; and right, the '*idea in*' the product – its technical oriented design and realisation context (Hansen & Andreasen 2002).

Value perceptions are used to guide the design of products and services and may be composed of several dimensions, e.g. utility, social, emotional and spiritual (Boztepe 2007), yet in Engineering Design literature the utility and function embedded in the product in relation to its costs is traditionally considered the primary component of technical value (Pahl & Beitz 1996).

A more appropriate focus to understanding value would be, not to consider the product or service itself, but instead consider the effect they induce on stakeholders. One way of elucidating the value of a product or service is to look at the activity that emerges from the interaction that a product or service has with a stakeholder within a context (McAloone & Robotham 1999). Vargo and Lusch (2004) make the distinction between '*value-in-exchange*' and '*value-in-use*'. The former is determined by the customer and based on the transfer of ownership of products and their physical distribution. The latter is determined by the customer and

based on the benefits achieved through activities involving the products. These different perspectives of value characterise the shift from traditional products to PSS, where value is not considered to be embedded in the physical product but is created by supporting and enhancing the customer's utility of the product.

Companies seldom consider the broader view of value. A product's value should also be viewed in relation to the activities and systems that it becomes part of throughout its entire life cycle. This is the focus in the literature on *Life Cycle Management* (Westkämper et al. 2000; McAlone & Andreasen 2002; Takata et al. 2004). A further expansion of a perspective of value is to see it in relation to the part it plays in a particular actor's total system of activities and overall objectives. Here the concept of value goes beyond the costs and benefits of the product throughout its life cycle but also includes the broader consequences incurred to the customer when purchasing, using and finally disposing of the product. This customer-oriented perception is typically called the total cost of ownership, and places the value of the product into a greater perspective allowing the focus to be on issues that would have the greatest potential of improvement. This approach is inherent in LCA methodology and related to *Activity-Based Costing*, but likewise suffers from discussions on what can be reasonably included and attributed to the product. Determining this in practice is a challenge as it requires a very detailed insight to a customer's operations. Nonetheless this perspective gives an idea of where efforts should be made in the development of new value propositions that is relevant to PSS (Windahl 2007).

Although not exhaustive Olesen (1992) suggests that the so called '*Seven Universal Virtues*' (costs, quality, flexibility, throughput time, risk, efficiency, environmental effects) should be considered in the entirety of the product's life. All of these virtues inform of different possible perspectives of value relating to the activities the product is a part of. Value is perceived differently by each of the product's stakeholders depending on their role and responsibility, and how they experience the product. For example, a product's value is perceived differently if it is sold or leased, as the trade-off between incurred costs and liabilities for the customer is different (Fishbein et al. 2000). A particular perspective of this is to see value in relation to the customer's value chain activities in using and maintaining the product from sale to disposal (Mørup 1993; Wise & Baumgartner 1999). For example a car after purchase requires financing, insurance, petrol, maintenance & repair, etc. Besides the purchase price of a car the customer has to consider fuel efficiency, risk of breakdowns and how to maintain a high resale value.

Engineering literature has focused on the above perspectives of value as they are to a certain extent quantifiable. Life cycle engineering, life cycle

cost analysis, life cycle (environmental) analysis, customer life time value, reliability, maintainability, usability, supportability, manufacturability, etc, are all examples of methods used to determine value (Blanchard & Fabrycky 1998). Often overlooked however but sometimes of major importance are other (qualitative) value perspectives such as sentimental attachment, appearance, surprise, comfort, pleasure, delight, pride of ownership, originality, uniqueness (e.g. limited editions), historical significance (e.g. antique), identity, philanthropy, etc (Norman 2004; Chapman 2005). These value perceptions tend not to be well defined and the difficulty of articulating them results in that many engineers today struggle to grasp the full breadth of value perceptions (Guldbrandsen 2006).

According to Levitt (Levitt 1980; Kotler & Keller 2006) a value proposition is composed of five levels (Levitt applies the broad use of the term *product* here):

- the **core benefit** is the fundamental reason a customer is interested in the proposition (Levitt called this the generic product, but Kotler and Keller later referred to this as the core benefit.)
- the **basic product** is the actual material and/or immaterial realisation of the core benefit
- the **expected product** is the set of attributes and conditions that a customer expects.
- the **augmented product** is the systems and services that can be offered to support the customer's activities.
- the **potential product** encompasses all the future possibilities for what the company may provide with the product.

Here value is structured as multiple levels that a company can address when marketing value propositions, but does not necessarily inform how a customer experiences value.

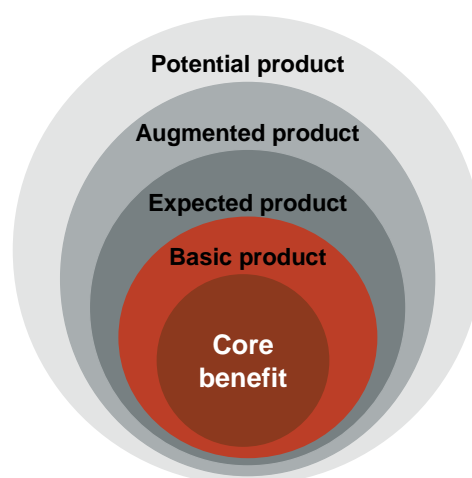


Figure 2.3 The five product levels that contribute to customer value (Kotler & Keller 2006).

The nature of these value propositions determine what the design object is. If the value proposition is predominantly related to something physical and value is based on the exchange of ownership from company to customer (*value-in-exchange*), it is traditionally called a good or a product. On the other hand, if the value proposition is predominantly related to something immaterial and the value is based on the activity, deed, process or interaction between the parties (*value-in-use*), this is called a service. Levitt's/Kotler and Keller's model shows however that both physical products and intangible services are required to provide value to a customer. The configuration of value propositions is key to how companies may differentiate themselves strategically to achieve competitive advantage (Levitt 1980). All levels of a value proposition need to be addressed by a company and the design task is to determine the objects that can provide the total value proposition. Gilmore and Pine (1997) describe how companies remain competitive by upgrading their value proposition from commodities to products, services, experiences and ultimately transformations that change a customer's life (see Figure 2.4).

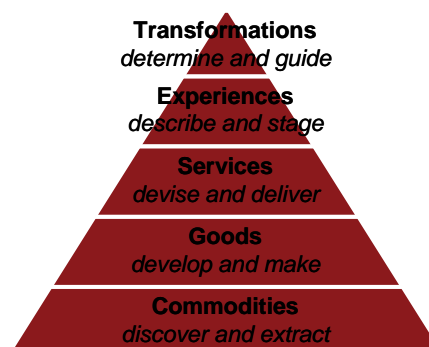


Figure 2.4 The progression of economic value from simple commodities to life changing transformation together with the change of focus on what is the task to be performed (Gilmore & Pine II 1997).

The design object changes each time a company moves from one level of value proposition to the next. In the following various manners of describing these design objects are considered.

2.3 Products and services

All products are delivered with services such as sales, delivery and support, and every service involves physical products, infrastructures and environments in order to provide the benefit (Shostack 1987). In this thesis the focus is on services as seen from the perspective of a manufacturing company. Here several typologies of services have been proposed with each typology dependent on the perspective of the researcher(s). Some typical services and different types of classification are shown in Figure 2.5. It is worthwhile noting here that the word 'service' has multiple meanings and therefore leads to some confusion in Engineering Design and manufacturing literature.

Service may be understood as:

- the basic and general activities relating to the purchase and delivery of products;
- the activities relating to the maintenance and repair of products;
- the performance or support of the use of products;
- supporting customer activities;
- assuming responsibility for customer activities or products; or as,
- the achievement of results for the customer.

These services may include the renting, leasing, access or other kinds of usage of products/equipment, personnel/competencies, space/facilities and infrastructure/networks (Lovelock & Gummesson 2004). As can be seen in Figure 2.5, the term service covers a broad spectrum of offerings and as Edvardsson et al. (2005) conclude *“that services are as different from each other as products are from one another”*. Nonetheless, there is a need to have a clear language that allows manufacturers and designers to communicate and share a common understanding of what services mean in PSS.

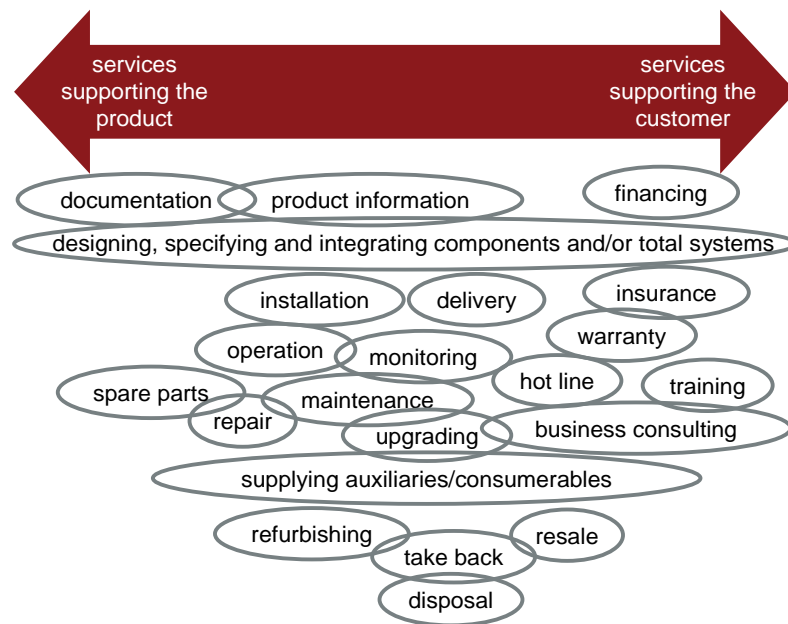


Figure 2.5 Manufacturing firms can offer a wide range of services: some cater more to supporting the product, whilst others are not dependent on the product but support the customer (Mathieu 2001a; Oliva & Kallenberg 2003).

As with products, the circumstances for development process and business strategy are interdependent with the characteristics of the service (Gebauer et al. 2008). For example, customer services, repair and maintenance tend to be more standardised than consulting, which is more similar to one-off products (Antioco et al. 2008).

Engineering Design literature has traditionally focused on tangible, technical products as design objects (Pahl & Beitz 1996; Ulrich & Eppinger 2003), and has only recently begun to consider the design of

services (Hollins 2006). This expansion of the scope of design into services raises questions about our knowledge of design. How should the design of services be approached effectively and efficiently? Is the current knowledge adequate when the design object is not a physical, technical artefact? In general products and services are two means of providing added-value to customers. Products do so by transferring the rights and ownership of physical artefacts. Services do so through the performance of activities.

Value mainly in product content	PRODUCT/SERVICE-SYSTEMS			Value mainly in service content
	Product content (tangible)		Product content (intangible)	
PURE PRODUCT	PRODUCT ORIENTED	USE ORIENTED	RESULT ORIENTED	PURE SERVICE
	1. Product related service 2. Product related advice/ consultancy	3. Product leasing 4. Product renting/ sharing 5. Product pooling 6. Pay per service unit	7. Activity management 8. Functional unit	

Figure 2.6 A typology of PSS that span from product-oriented to service-oriented (Tukker & Tischner 2006).

It is only in the last 30 years that the design of services has attracted attention from researchers (Grönroos 2000; Rust & Mui 2006). In order to justify their interest in services, early research in the area was focused on attempting to determine differences between products (physical goods) and services which argued that they had to be designed, marketed and managed differently. Four differences are often mentioned as distinctive for services; *intangibility* (they cannot be perceived before purchase), *inseparability* (they are typically produced and consumed at the same time), *variability or heterogeneity* (their quality is more variable) and *perishability* (they cannot be stored). Early research in services led to the build up of a 'products versus services' division where everything had to be redefined from scratch in relation to services. The research was directed at service firms (e.g. airlines, hotels, restaurants, banks, insurance companies, health providers, consultancies, etc.) which had been overlooked in the manufacturing oriented literature. This research in services gave service organisations ways to understand and improve the design and delivery of their services (Shostack 1982).

Today the product versus service distinction has been renounced by most researchers as an oversimplification and too narrow a definition (Edvardsson et al. 2005). The characteristics of products and services of different industry sectors can be very different but this is not to be confused with products and services from the same industry sectors. From the perspective of offering a certain value proposition, products and services are merely value creating components that together aim to

fulfil the same identified needs. For example, when considering a service, such as a bank loan, and then a product, such as a car, these are two completely different things with little in common. But when considering car leasing (a service) in relation to purchasing a car (a product), there are far more similarities than differences. They both provide the same core benefit and the technical physical artefact is the same. Ownership, responsibility of performance and the availability of the car is of course different in each case and perhaps what ultimately determines the customer's preference (Lovelock & Gummesson 2004). But instead of seeing products and services as two separate value propositions, they should be seen as alternatives to providing the same value. Or as described by Brezet et al. (2001): *"The impression that a reader gets from this literature is that products are substantially different from services. [...] these two categories are merely different modes of delivering satisfaction and that the dichotomy established in much of the current literature clouds the basic design issues involved in the more important goal of finding more sustainable ways to satisfy demand. It is not the difference between product and service, but the design of the artefact, its institutional (or infrastructural) context, and the consumers' practices-in-use that are the critical factors determining its effectiveness in promoting sustainability."*

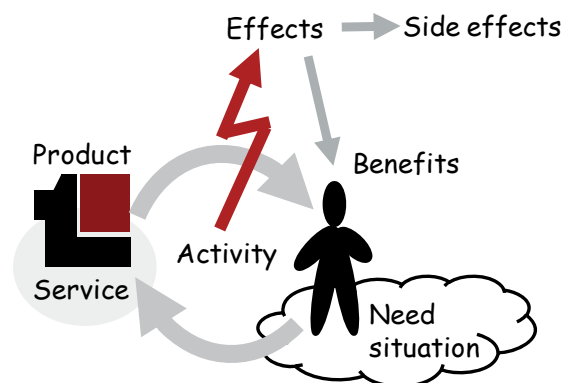


Figure 2.7 A value proposition is composed of the products and services as well as the perceived benefits they provide. With value-in-use the benefits are derived from the interaction with products and services.

It therefore does not make sense to have a sharp distinction between product and services. Products provide services, and services require products. They are always bundled together in some way (Normann & Ramirez 1993). What is important is realising that needs can be fulfilled by both products and services (and often a combination of both). What is traditionally seen as a product can sometimes be offered as a service. In the end it is not products or services that customers buy. What they actually buy are the benefits (the utility and other attributes) that products and services provide them with (Normann & Ramirez 1993; Gummesson 1995; Grönroos 2000). From this perspective all companies basically offer services, even manufacturing firms (Levitt 1972; Gummesson 1995).

From the perspective of design, it is not so much about what the different characteristics of products and services are, but rather how products and services can be combined to provide benefits that together are better value propositions. Product and services should be viewed on equal terms as means to fulfilling needs. If products can be substituted with services to create a better solution then this is no different from any other design task where the objective is to find the best solution. In essence both products and services are just two modes in which companies attempt to deliver value to their customers. The 'product' versus 'service' discussion is not so much an issue of a new 'object' that has to be developed, but a new perspective on what kind of value is being created.

2.3.1 Service-dominant logic

What differentiates products and services is their different characteristics of what is offered to the customer, but a distinction between two paradigms that are representative of different management perspectives: a service (customer) oriented view and a product (manufacturer/provider) oriented view on value creation (Gummesson 1995; Grönroos 2000; Vargo & Lusch 2004; Edvardsson et al. 2005). This is not to say that since services and products are the same thing and nothing changes, on the contrary one should try to understand and seek new opportunities using these different interpretations. Lindberg and Nordin (2008) demonstrate that the product-dominant logic and service-dominant logic are not mutually exclusive for the provision of products and services. This is particularly apparent in the procurement process where there is a need at one point of time to objectify products and services in order for them to be exchanged. Likewise specifications and contracts need to be objectified and agreed upon, so that everybody has a common understanding of it and tasks can be broken down and delegated. It is suggested that instead of trying to define differences between products and services, it is more useful to take a service-oriented view to design. When only considering products as a value proposition "*[i]t is left to the user to transform the purchase of a product into something that fulfils effectively a final user need*" (Tukker & Tischner 2006), whereas a service perspective opens up to opportunities to better support and enhance the utility of the product throughout its entire life. As will be shown in the following, a service perspective reveals a more comprehensive approach to the design and development of products and enables the generation of new and radically improved solutions.

2.3.2 Product/Service-Systems

With the above discussion on products and services and how they are always intertwined, it does not seem to make sense trying to distinguish what a PSS is. It is not possible to determine whether a value proposition is a product, service or PSS on its own. To be able to do this

it is necessary to determine how the value proposition differs to what has traditionally been offered to customers. Here a PSS offering is a result of a shift in business orientation from material products to immaterial services that at the same time will motivate companies and customers to increase material efficiency and reduce material consumption. In the following, theories that aid in understanding products and these new service-oriented natures of what a design object can be, are discussed.

2.4 Design objects

2.4.1 Products as design objects

The first theories of Engineering Design originated from machine design (Reuleaux 1963) which elucidates that the majority of the current literature is still concerned with the design of technical (and mechanical in particular) systems. In the following, existing theories regarding the design of products are discussed in relation to the service-oriented perspective presented in the previous section.

Theory of Technical Systems

Hubka formulated a theory for technical artefacts and used the term '*technical system*' to represent all types of man-made objects including products (Hubka & Eder 1988). Based on *general systems theory*, the *Theory of Technical Systems* is an approach to structure and model systems for analysis and synthesis. The Theory of Technical Systems provides a language to describe and model products and how they compose a part of a total *transformation system*. Each transformation system has a well-defined purpose which is to "*fulfil stated and implied needs*." Here technical systems are just one manifestation of an operator along with others such as human beings, information systems, management systems and the immediate environment. These operators act on operands that are elements of the transformation process. Operands can be material (both biological – including humans – and non-biological), energy and information. The operands are defined by their *existing state* and a *desired state of need fulfilment*. Central to Hubka's theory is the *model of the transformation system* (Hubka & Eder 1988), see Figure 2.8.

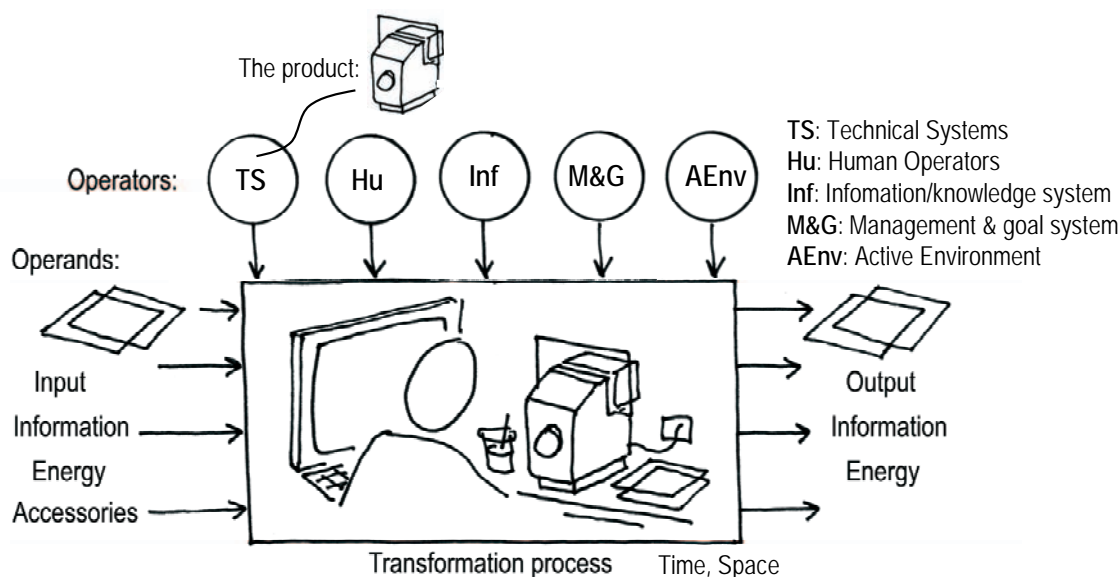


Figure 2.8 Illustration of the use of a product in a model of the transformation system, showing operands and operators (Hubka & Eder 1988).

Technical systems are part of a transformation process which corresponds to an activity and therefore could be used to model a service. It shows how the operators of a service system interact with each other in time and space. Transformation systems have the following operators that influence the transformation process:

- **Technical systems** (i.e. products) based on these systems' functionality.
- **Human systems** that on one hand can be contributing operators, and on the other, the persons in the transformation process that act as carriers of and channels of information, control, management, etc.
- **Information systems** that provide the necessary information for the transformation, e.g. installation guidelines, recipes, know-how, instructions, knowledge of the phenomena, reference data, etc.
- **Management and goal systems** that manage and control the activities and the systems' coordination, certification, norms, standards, etc.
- **Active environment** and conditions in the form of physical surroundings, socio-technical conditions, societal conditions, financial circumstances, etc.

The listed operators correspond to the components of the service system as proposed by researchers in *service design* (Goldstein et al. 2002; Bullinger et al. 2003; Hackett 2007). According to these researchers, service delivery system includes people, technology, physical facilities, equipment and the processes by which the service is created and delivered. All of these elements can be found in Hubka's *Transformation Model* as it provides a general description of the structure of an activity. Hubka's model affirms that a product's utility only emerges when it is

used or employed in a transformation process or activity. It also shows that a product cannot perform the transformation process on its own, but requires interaction with other operators that are responsible for the product's use. Even with simple use of products there is an underlying management and goal-setting system that assigns the task of each element. Finally Hubka's model suggests that the product's utility value for the user is dependent on the output of the transformation process, but the model does not provide any insight to why this creates value for the user.

Theory of Properties

All systems have *attributes* that can be *structural* or *behavioural*. The structure of a system is determined by its components and their relations to each other. Humans value technical systems because that they can exhibit behaviour that satisfies needs (Hubka & Eder 1988). The purposeful behaviour of a technical system is often referred to as its function. In other words, the structural attributes define '*what a system is*', whilst the behavioural attributes describe '*what a system does*' (Andreasen 1992).

Hubka's Transformation Model (Hubka & Eder 1988) splits traditional function reasoning (Pahl & Beitz 1996) up into two kinds of functionality:

1. the product's function seen as the product's ability to deliver desired effects; and,
2. the transformation created by using the product.

The first notion is related to the product's structure, the second one is related to the technology (or activity) of using the product, i.e. the interaction of product, user, context and the operand which is transformed. A drilling machine delivers rotation and torque (functions). It can be used for drilling holes, whipping cream, mixing paint, etc. (technologies) resulting in desired transformations or end results: holes, whipped cream, mixed paint (operands).

Based on Hubka's theory, Andreasen (1992) proposed that product's structural attributes are called *characteristics* (within the German engineering design community: *Merkmale*); and the behavioural attributes are called *properties* (German: *Eigenschaften*). To exemplify, a bicycle's characteristics are the materials, shape, dimensions and surface textures. A bicycle's properties are e.g. weight, friction of gears, cost, ease of maintenance, etc. This distinction in terminology is used throughout this thesis.

Properties in this perspective include function, functional properties and product life-oriented properties. The isolation of the product's use process and the overall focus on activities associated with the product's

life cycle has an essential importance when we approach services. Properties here are called *relational properties* and are determined through a combination of attributes of the product and the life phase system. For example, the recyclability of a product is determined by both the product and the disposal/take back system. As a note to the discussion of differences between products and services regarding *intangibility*, *heterogeneity*, *inseparability* and *perishability*, they are, according to Andreasen, all properties and not characteristics. A service can be made tangible, homogenous, its production can be separated from consumption and its capacity can be managed.

According to Hubka (Hubka & Eder 1988), the properties of a technical system depend on the characteristics of the system. A fundamental aspect of design is that behavioural properties cannot be determined directly by designers. Designers may only determine the structural characteristics of a technical system in order to achieve the desired properties. In design terms, the process of predicting a product's properties from known characteristics is called *analysis*, whilst the process of assigning the characteristics of a product from desired properties is called *synthesis* (see Figure 2.9). Weber et al. (2004) have attempted to model PSS based on this approach of modelling characteristics. Although the researchers propose a schema for characteristics and properties of services, this has not been well integrated with products; particularly the role of the customer in services is not clarified.

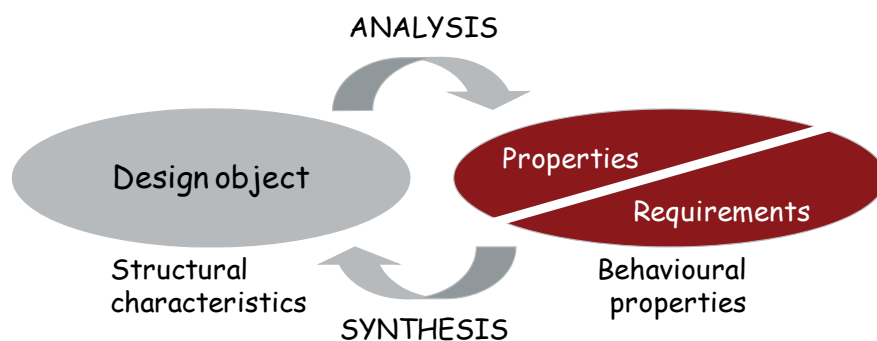


Figure 2.9 Analysis determines properties from known characteristics, whilst synthesis assigns characteristics from required properties (Weber et al. 2004).

Mortensen (2000) distinguishes between four classes of attributes:

- *characteristics* are the only attributes a designer may determine directly. E.g. structure, form, dimension, surface quality and material.
- *inherent properties* cannot be determined directly, but are causally determined by the characteristics and the environment. E.g. strength stiffness, durability, corrosion resistance, etc.
- *relational properties* are the attributes that appear when the technical system encounters a life phase system, e.g. assembly, installation, disposal, etc. Relational properties are determined

by the characteristics of both the technical system, the human being and the life phase system. E.g. Cost, time, quality, efficiency, flexibility, risk, environmental effects, etc.

- **quality** is the perceptions and expectations of stakeholders around the technical system. It is difficult to determine the causality of quality as it is determined between the aforementioned attributes and individual humans' perception and value system. E.g. emotional attachment, pride of ownership, pleasure, delight, etc.

Andreasen (2007) also includes:

- **functional properties** that inform how well a function is realised, e.g. the function of a thermometer is to show the temperature. The functional properties are then the resolution of temperature markings, the accuracy of the display, the responsiveness to temperature change, etc.

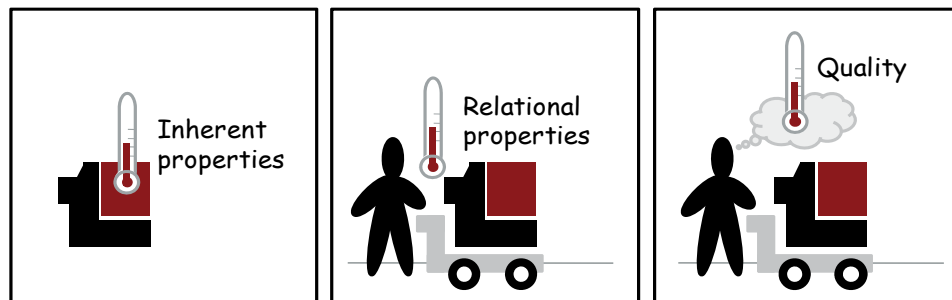


Figure 2.10 Different classes of properties regarding a product (Mortensen 2000).

The concepts of systems, structure, attributes, behaviour and value are key to understanding design objects. The Theory of Technical Systems and the Theory of Properties inform us that the structure of technical systems influences the systems behaviour, but the behaviour does not predispose a unique structure. The same behaviour can be achieved and realised by different structures. Or rather: There are several solutions to the same problem. As services are activities and processes, and may be modelled as transformation systems they too have structures and behaviours and therefore can be approached in the same way products are designed.

Theory of Domains

Building upon a theory originally formulated in 1992, Andreasen's (2007) *Theory of Domains* provides three system perspectives of technical systems appropriate for synthesis (the function system view has since been eliminated as it and the organ view are respectively the behavioural and structural view of the same thing):

- **A process system view** is a description of the operands that are transformed from one state to another to give the desired benefits, e.g. a document is electronically scanned from a piece of paper to a digital format.

- *An organ system view* is a description of the embodiment of the functions and describes the structural design of the system, e.g. the Charge-Coupled Device array is the core component in a scanner that can capture a reflection of an image and convert it digitally.
- *A part system view* is a description of the basic individual physical parts of the technical system. A part is produced by one material without assembly operations, that when assembled together they form organs, e.g. gears, screws, electrical wires, etc.

These perspectives of modelling technical systems are related to three different design objects which each are interrelated in a causal chain. Mortensen (2000) suggests that the process system view is related to the modelling of activities that occur when the product, human and life phase system interact with each other. The function, organ and part views are related to the technical system (product) alone. The Theory of Technical Systems together with the Theory of Domains gives an idea of how both products and services may be modelled.

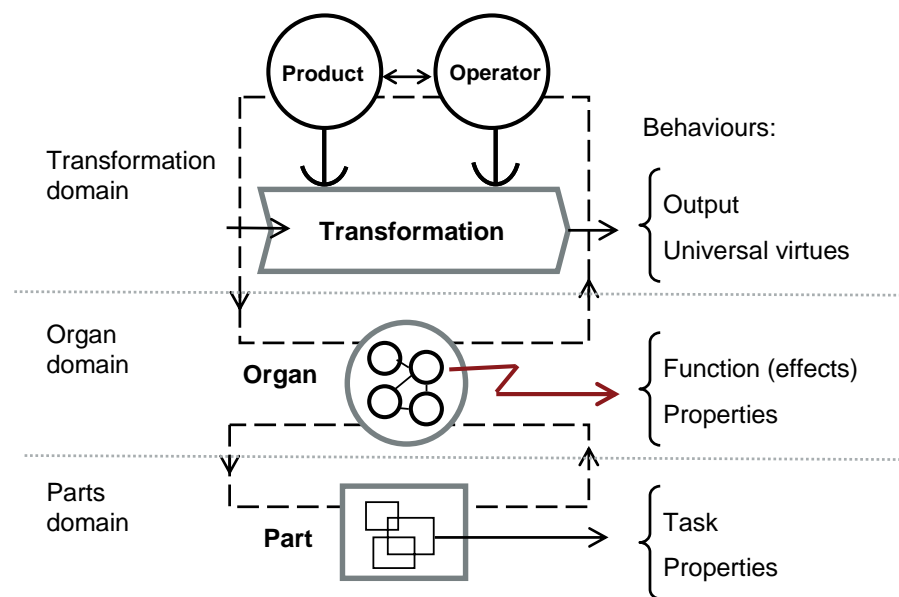


Figure 2.11 The Theory of Domains incorporates three perspectives of technical systems that may be considered design objects. Adapted from (Hansen & Andreasen 2002).

The above mentioned theories from Engineering Design appear to be relevant and may be applied to services. However, there are some aspects to services that seem to be missing:

- Using Hubka's Transformation Model to describe services does not lead us, to all types of services. First and foremost, services are not only deliveries, but can also be 'insurance', i.e. services that are only prompted and provided in the case of failure, late delivery, machine down time, accidents, and so on. From this perspective, financial support to maintain operation or compensation for down time is also a service.

- The design of a service relates as much to the other operators of a transformation process than to technical systems (i.e. products). Although these are represented in Hubka's theory, the design and development of humans (e.g. training, recruitment), information systems (e.g. learning), management and goal systems (e.g. roles and responsibilities) and active environment (e.g. place and space) are not traditionally considered as product development tasks. From a service perspective the design object therefore needs to be expanded.
- With services there is a greater opportunity to ensure that the output of the transformation process corresponds to the desired goals. Feedback is implied in the Transformation Model (Hubka & Eder 1988), but this is not elaborated on in relation to the complete chain of activities that occur during a product's life. Olesen (1992), as we shall see later on, emphasised the importance of understanding these relations during the design process.

In general, the product-oriented models from Engineering Design do not describe the interaction and importance of the (customer) activities surrounding the transformation process. Customer's activities are very fundamental for understanding how value is provided to the customer. The current design models do not tell us much about how operators are organised, the customer's progression of activities or how value is delivered to the customer. Therefore four other theoretical contributions are selected in order to integrate more service-oriented perspectives. These are Service Blueprinting, Customer Activity Cycle, Network of Actors and Service Engineering.

2.4.2 Services as design objects

Theories of service from a design perspective are fairly young. In the 1970s scholars in marketing established services as an area of its own and worthy of investigation (Cook et al. 1999). Typically, services from traditional service firms (e.g. banks, hotels, restaurants, etc.) were modelled to make them concrete and, like products, show that they too had a structure. The purpose was not so much to create new forms of service, but to evaluate existing services and identify how they could be optimised.

Service Blueprinting

One of the early researchers in the area of service design was Lynn Shostack (1982). She proposed a conceptual model for deploying a service idea. The model maps user experience in relation to time, resources, and stakeholders. Figure 2.12 shows an illustrative example of a service blueprint. The user's or customer's chain of activities is laid out as the backbone of the model and the related physical evidences are denoted (these are called the active environment and conditions in

Figure 2.8). The blueprint's service activities are modelled as person related activity chains that are engaged with the customer's activity chain. All processes that contribute to the customer experience are visualised and the roles of each of the operators are described. These processes run in parallel with the customer's activities and are often 'behind the scenes' (not visible to the customer). This form of modelling allows – as Shostack shows in other examples – an integration of artefacts and activity types of services, but do not show the reasons (or value relations) for the customer's interest in services. Service blueprinting is related to storyboard and interaction techniques (Vezzoli 2007).

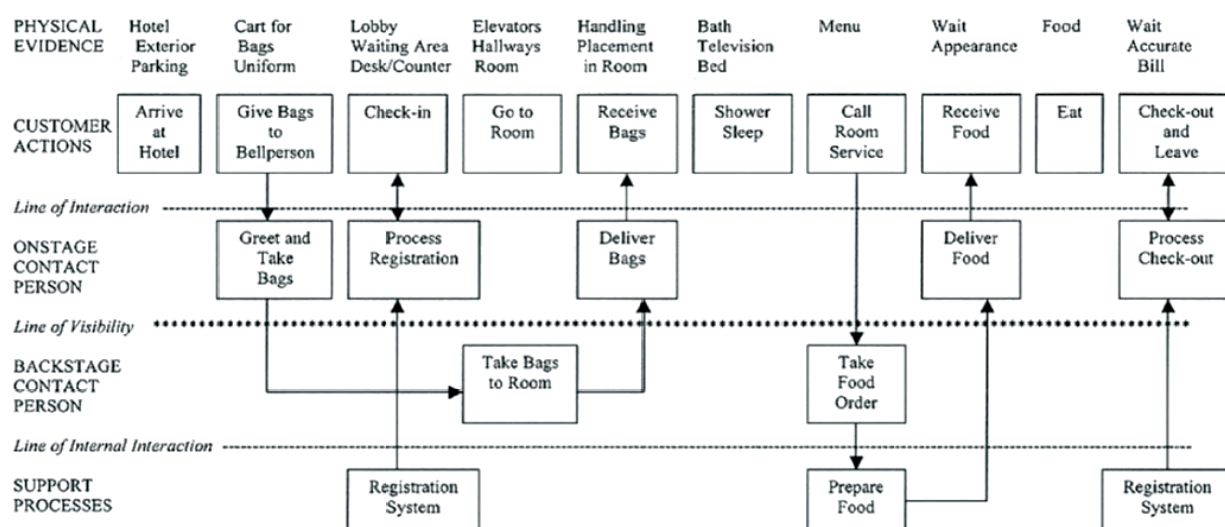


Figure 2.12 An example of a Service Blueprint for service activities related to a hotel stay (Shostack 1982).

Service prerequisites

Similar to theory of domains Edvardsson and Olsson (1996) distinguish between three design objects regarding services (see Figure 2.13):

- *the service concept* is the benefits and value the service intends to provide. This corresponds to the term 'value proposition' used in this thesis.
- *the service process* is the chain or chains of parallel and sequential activities that deliver the service. This matches the process perspective in Domain Theory but also includes customer activities. The outcome of a service is often dependent on the customer's behaviour. Although this cannot be directly controlled by the service provider the role, participation and responsibility of the customer must be made clear.
- *the service system* is the resources required to offer the service consisting of employees, customers, physical and technical environment and organisation and control. These are identical to the operators and operands in Hubka's Transformation Model. Akin to the organ domain, this describes the entities necessary to deliver the desired effects.

Notice here that in relation to products the customer plays a major role in services. It is not possible to design employees or customers or their behaviour directly, but there are many ways to inform, educate, support and encourage or discourage their actions (Bitran & Pedrosa 1998). Knowledge of how to do this is different from knowledge about technical systems (which are based on understanding physical principles) and more related to social-technical understanding. Researchers and practitioners operationalise this internally in companies by developing a so-called 'service culture' (Edvardsson et al. 2000). Due to the soft systems nature of services, the modelling of services is difficult to do as behaviour is not always logically predictable (Bitran & Pedrosa 1998).

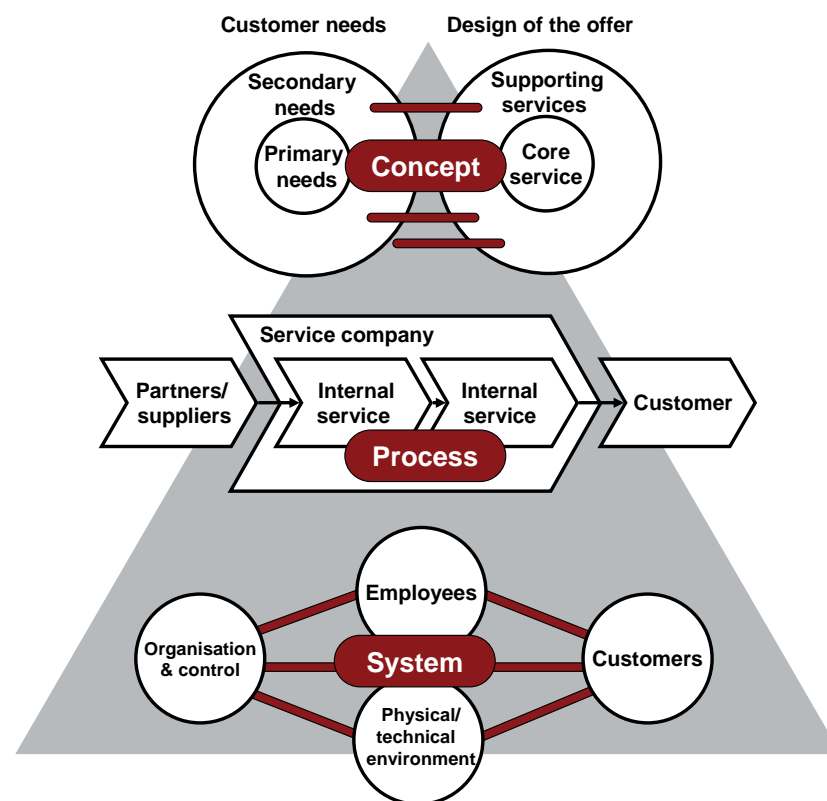


Figure 2.13 Model of the prerequisites of service based on the three components: service concept, service system and service process (Edvardsson & Olsson 1996).

Also apparent is that the result of service design is only a prerequisite or potential of a service and that the actual service process may deviate considerably from the original design (Shostack 1982; Edvardsson & Olsson 1996). Although companies aspire to design services reliably, consistently and replicably, services should be flexible and adapt to contextual differences (Bitran & Pedrosa 1998). Understanding the use situation would therefore seem to be of great importance when developing products.

Relationship Marketing

A new paradigm in marketing called 'Relationship Marketing' has emerged out of service marketing (Grönroos 1994). In contrast to the view of marketing as the transfer of ownership of products, relationship marketing aims "to establish, maintain, and enhance relationships with customers and other partners, at a profit, so that the objectives of the parties involved are met. This is achieved by a mutual exchange and fulfilment of promises" (Grönroos 1994). Here the perspective is that value "is created for customers in long term customer relationships" (Grönroos 2007). The goal is to gain the strongest relationship with the most profitable customers (Wise & Baumgartner 1999). Considerable research has been done in understanding the customer experience and perceptions of value. Typically products and services are only considered in one episode regarding the customer (Ravald & Gronroos 1996) and not the entire customer value chain.

Customer Activity Cycle

Vandermerwe (2000) elaborates on how companies may focus on customer relationships through a methodology called 'Customer Activity Cycles'. Its focus is on the activities that customers go through to get the benefits of the offered products and services. A customer activity cycle consists of three stages (see Figure 2.14):

- *pre*, what goes on before the customer achieves the result;
- *during*, what happens while the customer derives the core benefit; and,
- *post*, what happens after the experience.

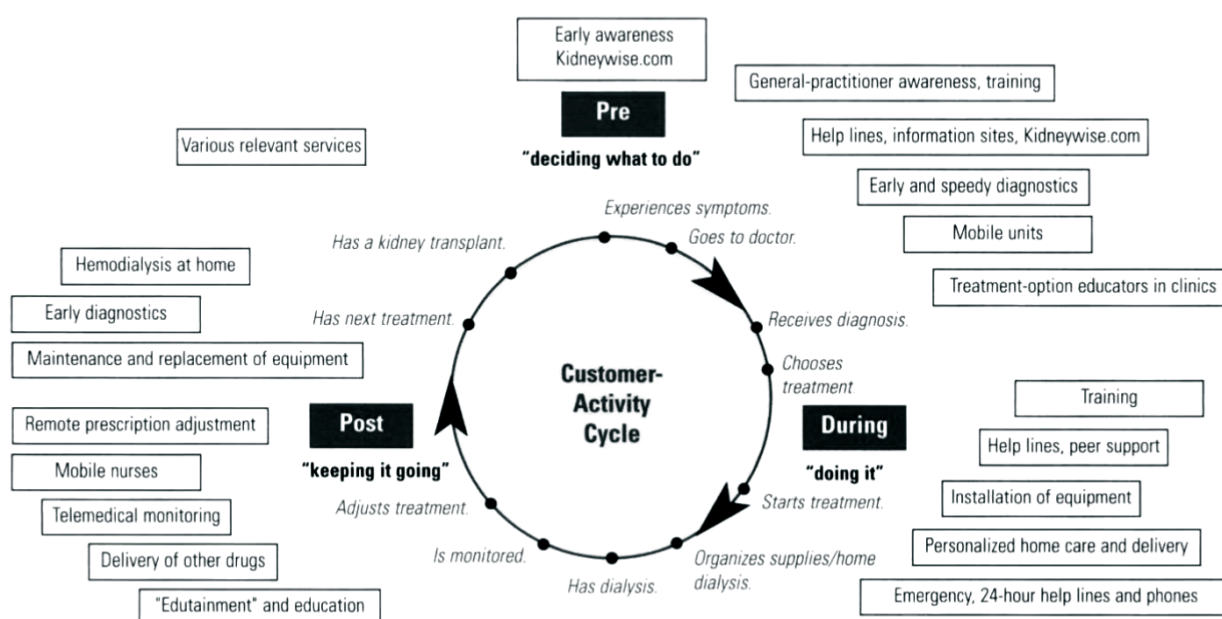


Figure 2.14 Example of a Customer Activity Cycle for patients with a serious kidney disease (Vandermerwe 2000).

By describing customer's full sequence of activities, activities where the customer could be better supported become apparent. Vandermerwe states that the Customer Activity Cycle model can help enable companies to identify offerings that they should strive to provide with value - either directly or indirectly.

Sawhney et al. (2004) indicate there is growth potential for manufacturers in both the primary customer activity chains and also the adjacent (or comprehensive) customer activity chains, by either adding new activities or reconfiguring the structure and control of activities. Using a similar approach with eight generic steps customers go through to perform a task, Bettencourt and Ulwick (2008) elaborate on how mapping customer activities leads to opportunities for new products and services.

2.4.3 PSS as design objects

From the perspective of Engineering Design, the design object in PSS changes from being not just a physical technological artefact, but an entire system that creates a social contextual experience for multiple stakeholders. The previous sections' review of theoretical design relevant product and service models, has elucidated on what the design object is (or actually what the design objects are) in PSS. When applying a service perspective, several design dimensions not traditionally considered in Engineering Design become evident. Besides the product itself, its life phase systems, delivery channels, customer activities and actor network should be addressed as design objects too. In this section the literature on PSS as a design object is consulted and discussed.

Product Life Thinking

From a manufacturing perspective Olesen (1992) emphasises that the life cycle system of products (i.e. production, distribution, sales, operation, disposal) and the development of these systems should be considered during design. Engineering Design does not consider these service channels as a design object in itself and typically perceives the product as having to adhere to whatever delivery system is already in place. Hein (2000) points out that designers attempt to not only develop product concepts, but also concepts for the life phase systems that products encounter. As stated earlier a product's (relational) properties only become apparent during an encounter with the life phase system and the total transformation system. Being able to design and manage the life phase system as service channels provides companies an opportunity to better ensure a product's properties are attained (Berggren & Nacher 2001).

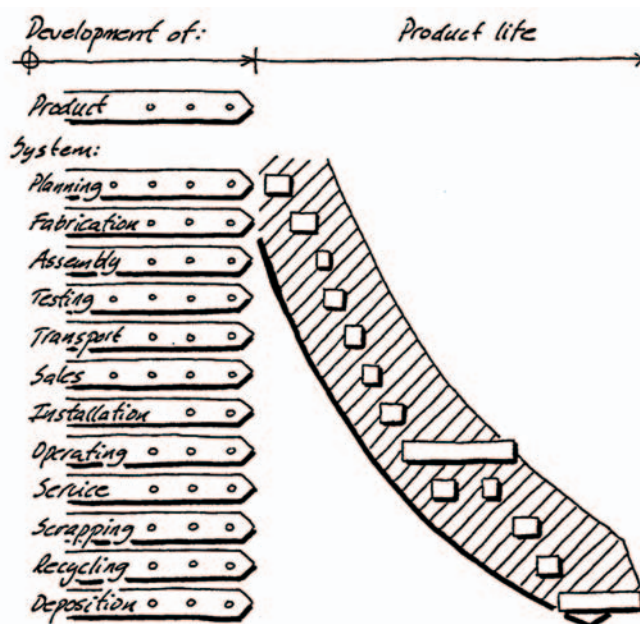


Figure 2.15 Olesen's score model that shows that not only the product is developed but also each life phase system must be developed (Olesen 1992). Product life thinking involves matching the product and all its life phase systems to each other.

Typically existing product life systems are re-used to provide the effects of products. In relation to sustainable product development the importance of matching the product to its product life systems is critical. Some researchers claim that one should “*first design [the] total product life cycle*” before designing the product (Kimura & Suzuki 1996). Product life systems can be modelled as transformation systems, with its own operators (technical systems, humans, active environment) that act on products, e.g. a distribution system might include trucks, drivers, packaging, pickup schedules, roads, fuel, etc. Interestingly in a service-oriented perspective, products themselves are considered to take the role as distribution mechanisms for services (Vargo & Lusch 2004).

Mortensen (1999) identifies at least three types of design objects that are synthesised in Engineering Design: the product itself, the life phase system and the encounters (or meetings) between product, actor and life phase system (Olesen et al. 1996). Although, it would seem that Engineering Design already seems to encompass all the design objects of PSS, they are not brought together and the opportunities that arise from them all are not exploited.

McAloone and Andreasen (2002) recognised how product life thinking could be utilised to expand the design object in product development to include life phase activities and ultimately aim for the development of PSS. Building upon the insight of parameter relationships between products, actors and life phase systems can result in improved product performance (Hansen 1997). One could say, where traditional product development aims at developing the right product, PSS aims at developing the right fit between product and life phase systems.

Service Engineering

Based on his formulation of a 'post-mass-production paradigm' which adheres to sustainable development principles, Tomiyama (2001) proposed a framework to understanding services and PSS. Based on an engineering approach, Tomiyama defined the key elements of a service and related them to each other: "A *service receiver* receives *service contents* from a *service provider* through a *service channel*. Service sent by the service provider changes the *state of the service receiver*, which is the most important feature of service as [an] activity" (see Figure 2.16).

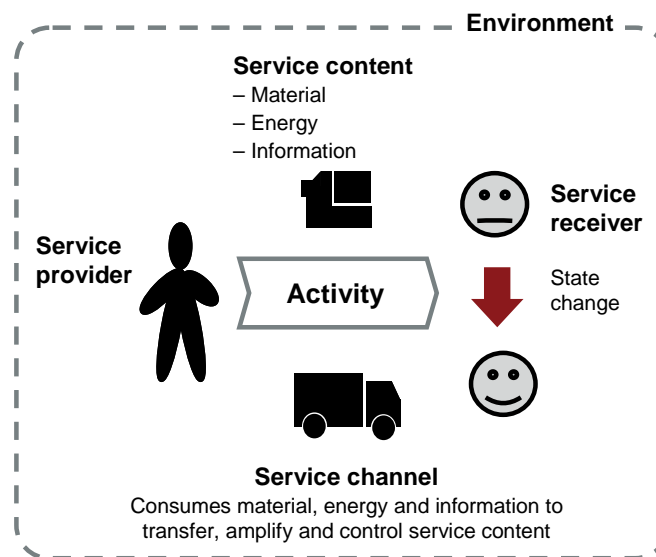


Figure 2.16 The main elements of a service according to Service Engineering (Tomiyama 2005).

The 'service receiver' should probably be thought of as a metaphor, not (only) the person, but also what he or she does, when his or her activities change state. Tomiyama's definition of services includes both a product-oriented and service-oriented perspective, as a distinction is made between 'service content' (operands in the form of material, energy and/or information) and the 'service channel' (the delivery system or operators that transfers, amplifies and controls/manages the service contents). This clearly delineates two fundamental design objects in services: a product (service content) and delivery system (service channel).

Tomiyama furthermore includes the state change of the service receiver (or customer) in his model and thereby the realised effects or value of products and services. Conventional Engineering Design models mainly consider the product's performance, and stops short of the customer's reaction to the product's performance. In Service Engineering, it is clear what the aim of the activity is. It is also clear how value relates to both the service content and its channel. The relative importance of these influences is of course dependent on the nature of the product and the

actual stakeholder or user in question. For example, a typical leisure product such as a mountain bike may lead to a value perception mainly composed of the emotional (e.g. the thrill of mountain biking), social significance (e.g. identification with outdoor sports) and the industrial design of the bicycle.

According to Tomiyama (2005) the design process in Service Engineering is led by the 'service goal requirements' formulated in terms of receiver state change. Hence the service environment, provider, receiver, service receiver's activity aim (purpose of the transformation) and service target is given. This leaves the following design objects in service design:

- Service activity
- Service channel
- Service content
- Service information
- Service quality
- Service fee

The service activity corresponds to Hubka's Transformation Process of which the '*service information*' and '*service channel*' are operators (information system and technical system respectively) and the '*service content*' is the operand. This can all be described and is dealt with in current Engineering Design theory. '*Service quality*' in Tomiyama's proposal relates to the satisfaction of the service receiver (i.e. customer). In design, quality is not something that can be designed directly (i.e. it is not a characteristic), but is an experience of a design when it encounters a stakeholder and life phase system (i.e. it is a property) (Olesen et al. 1996).

Compared to the Theory of Technical Systems, the new aspect with Service Engineering is that it includes service receivers (i.e. customers) and their satisfaction in the same model. Although this is also addressed in *House of Quality* (or *Quality Function Deployment (QFD)*) (Hauser & Clausing 1988) the relationship between the product (or service) and the customer is only considered in the design process to formulate specifications and not when the product (or service) exists and has an actual effect. The formulation of the design task would be more effective if it could be based on the resulting state of the customer instead of "just" the means of how to achieve this. This would expand the mental scope for possible solutions for designers, but would also be difficult in practice as it requires a very intimate knowledge of customers and their value perceptions.

Tomiyama's proposal also includes the design of the service fee. This too is not explicit in current Engineering Design literature. The value relationships and why each of the actors involved in the activity are

motivated in participating in the service activity would be useful in understanding the business potential and behaviours of actors in the PSS.

In further development of Service Engineering, four models to describe services are used (Shimomura & Sakao 2006):

- *A view model*, which describes the structure of functions that change the receiver state and shows the service's channels and contents (see Figure 2.17). This integrates the function and organ system view in the Theory of Domains.
- *A scope model*, which maps the complete network of all the providers and receivers of the service including intermediate agents.
- *A flow model*, showing how the service provider, intermediate agents and receivers are related.
- *A scenario model*, which represents the service receiver's behaviour and state at each step in his activity chain. This relates the desired relational properties to each activity. This would correspond to the process system view in the Theory of Domains.

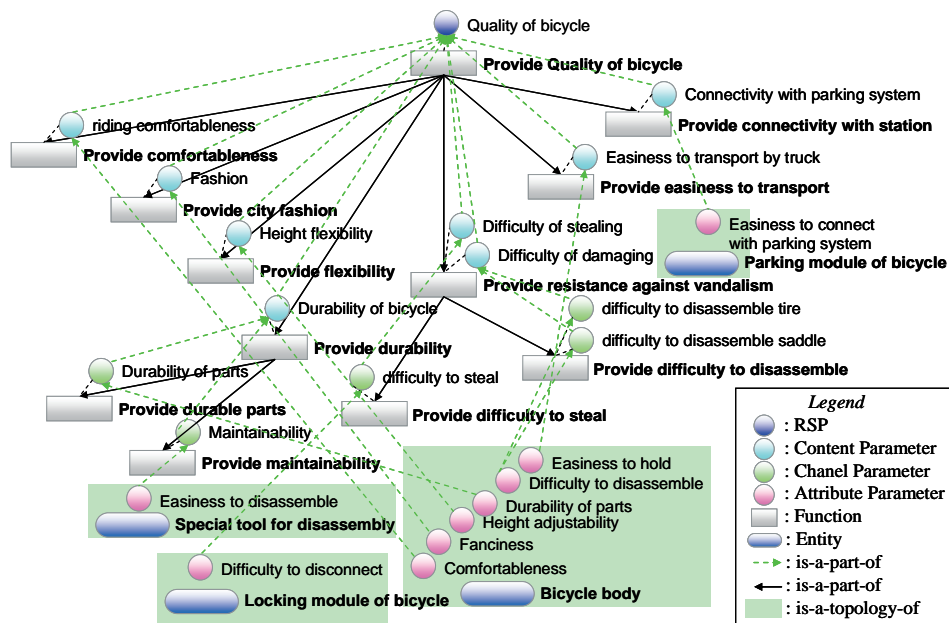


Figure 2.17 Service Engineering's view model of functions, channels, content and receiver state parameters in the case of a bicycle rental service (Sakao 2006).

By moving through the different design object domains (parts, functional organs and transformation process), the view model relates the characteristics of each service element to its functions and properties, whilst the scenario model connects these relational properties to the customer. The scope and flow models describe the actors related to the service and help designers understand the value relations between actors and the behavioural dimensions. This dimension will be examined further in the next section.

Actor Networks

Services and products are seldom delivered by just one party, but often demand a *network of actors* to provide the service (Manzini et al. 2004). Service Engineering stresses the importance of all actors (providers and receivers) of the service. By mapping the system of actors and the relations between them, an overview is created of how the actors are organised in order to provide the service. This enables designers to better recognise the motivations and incitements of the individual actors and understand their requirements. This is also what is achieved in Donaldson et al.'s (2006) *Customer Value Chain Analysis* methodology where “pertinent stakeholders, their relationships with each other, and their role in the product's life cycle” are identified and modelled (see Figure 2.14). This is similar to other visualisation methods, such as ‘System Organisation Map’ (Manzini et al. 2004) and ‘Stakeholder System Map’ (Vezzoli 2007). With these models it is possible to identify how value is generated in the whole network through service provision. An interesting aspect in this regard is that when doing this, the business model becomes apparent (Tukker & Tischner 2006). It is possible to identify how value is generated in the whole network through service provision, financial, material, energy and/or information flows.

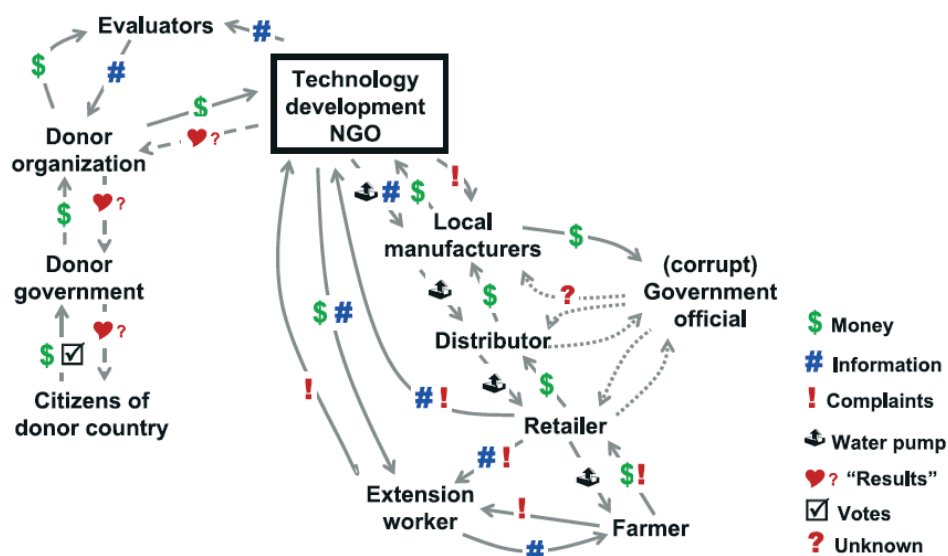


Figure 2.18 The actor network identifies all the active stakeholders around the product or service and maps the flows of value. The above is an example from a micro-irrigation pump developed by a Kenyan NGO and financed by foreign aid funds (Donaldson et al. 2006).

This type of modelling can be used to reveal opportunities to include other actors and stakeholders not considered in the current system, as well as how relations can be established and maintained. In the emerging service design literature this perspective is named ‘service ecology’ (Moritz 2005), but in this thesis the term ‘actor network’ is used. Here it covers a broader view of the supply chain that includes the

multitude of stakeholders in the production and consumption systems. The actors and their relations have to be arranged so that each actor is given an incentive to continuously reduce costs and increase resource efficiency (Manzini et al. 2004; Tukker & Tischner 2006).

PSS dimensions

Proposing a normative approach to PSS design McAloone (2005) brings the perspectives of product life thinking, customer activity cycle and actor-network together and describes how this is done in a student course. This approach is studied more in detail in this thesis as it appears to be a promising approach to systematic design of PSS.

Mont (2004) proposes that PSS consist of “*system of products, services, networks of actors and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and has a lower environmental impact than traditional business models*” (see Figure 2.19). Products are the technical systems; services are activities related to the product and the customer; infrastructure is the transformation systems that support the product throughout its life; and networks of actors are the broad range of active stakeholders throughout the product’s life. According to Mont each of these elements and their relations need to be designed concurrently to create a PSS. Mont uses the term ‘*infrastructure*’ but the understanding is the same as what is termed ‘*life phase system*’ in this thesis. It would seem that the models already considered cover all these elements, but what is lacking is the how these elements are causally related.

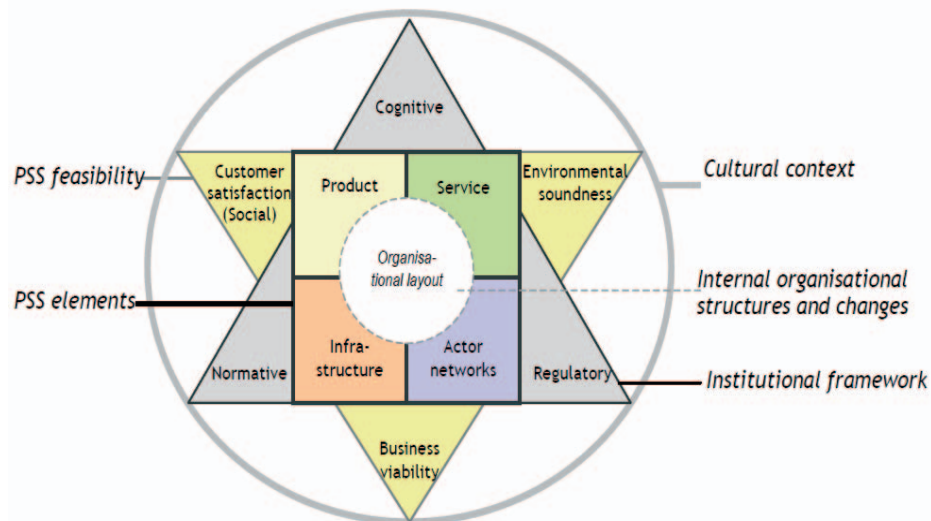


Figure 2.19 Mont's (2004) framework for analysing the elements of PSS and its sustainability criteria.

Mont furthermore refers to PSS as a business model. If PSS can be seen as a design object that can be modelled and this results in the formulation of a business model, can PSS design then be seen as a general method for designing new businesses?

According to Chesbrough and Rosenbloom (2002) the functions of a business model are to:

- Articulate *the value proposition*, i.e. the value for users by the offering based on technology;
- Identify *a market segment*, i.e. the users to whom the technology is useful and for what purposes, and specify the revenue generation mechanism(s) for the firm;
- Define *the structure of the value chain* within the firm required to create and distribute the offering, and determine the complementary assets needed to support the firm's position in this chain;
- Estimate *the cost structure and profit potential* of producing the offering, given the value proposition and value chain structure chosen;
- Describe *the position of the firm within the value network* linking suppliers and customers, including identification of potential complementors and competitors;
- Formulate *the competitive strategy* by which the innovating firm will gain and hold advantage over rivals.

It would seem that the design object models that have so far been presented to describe a PSS also define a business model, but they fall short of providing clarity on the value chain within the firm and competitive strategy. Although the modelling of PSS, does point to a business model, it does not fully define it. The overlap between PSS development and business development is also the main object in the book *"New Business for Old Europe: Product-service development"* (Tukker & Tischner 2006).

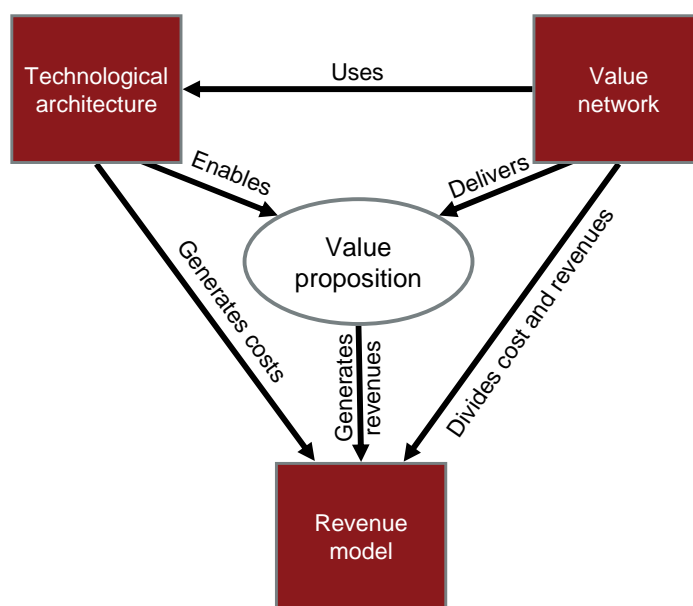


Figure 2.20 The elements of a business model as proposed by Ballon and Abranowski (2005) in *"New Business for Old Europe: Product-service development"* (Tukker & Tischner 2006).

Here a business model approach is found useful to conceptualise PSS, resulting in the identification of the following four dimensions (see Figure 2.20):

- *Value proposition*, the combination of products and services offered to the customer
- *Value network*, the actors involved in producing and using the value proposition
- *Revenue model*, the distribution of cost and revenue between the actors in the value network
- *Technological architecture/infrastructure*, the hardware needed to produce the value proposition

The value proposition determines how the value network, revenue model and technological architecture should be structured. Notice that the descriptions of the company's internal value chain organisation and how this relates to the company's (existing) business strategy are also lacking here. This is symptomatic of the major critique of current research on PSS design methodologies, which is that they have been investigated outside the context of manufacturing companies. A closer look at a manufacturing company's context and how it relates to PSS will be dealt with more in detail in Chapters 4 and 5 of this thesis.

2.4.4 Summing up – design objects

Services are often seen in relation to products, but it is not always easy to make a clear distinction between the two. Every product involves services such as sales, delivery and support, and every service involves physical products in order to provide the benefit. Instead, it appears that the service vs. product discussion is representative of two different management paradigms: a service (customer) oriented view and a product (manufacturer/provider) oriented view. This is not to say that since services and products are basically the same thing, nothing changes. On the contrary one should try to seek new opportunities using these two different interpretations. Applying both a product-oriented and service-oriented view allows a more comprehensive and open understanding of both products and services. It also expands the mental space in design as both products and services are possible solutions to problems and means to fulfil needs.

The shift in perspective from physical products to service systems represents a challenge for designers. Traditionally, the focus of design disciplines has been on physical artefacts rather than on services (Morelli 2003). With PSS the design engineer has to understand a broad scope of the new dimensions of customer (and stakeholder) value that traditionally are not considered in product development; e.g. user involvement, interaction experience, integration of systems, domestication (how new technology is appropriated by users), service delivery channel, after sales service, upgrading, ease of disposal, etc.

(Andreasen 2002). In this light, PSS calls for a need to expand both the traditional engineering design mindset, in order to be able to understand the proper nature of PSS and the expanded degrees of freedom in design, in order to carry out professional systematic PSS design.

2.5 Design processes

In the previous section, the end result or objective of design was discussed. In this section, the process of how value propositions are synthesised is considered. Theories of design processes have only really consolidated as an established scientific field in the last 50 years. Man has of course always performed 'design' activities but it is only recently that these processes were studied to understand how it could be performed more systematically.

Most design process models are based on the assumption that a system can be divided into subsystems (Bitran & Pedrosa 1998), as this

- forces a systematic search of alternatives;
- facilitates the design task by partitioning it into smaller sub-problems for later integration;
- requires that interactions among components be identified and analysed and which by itself may lead to a deeper analysis and better results.

Design process models seek to describe the complete chain of activities from need identification to successful business (Andreasen & Hein 2000; Ulrich & Eppinger 2003). The main components of these process models are *stages*, *activities* and *design strategies* (Blessing 1996):

- A **stage** (or **phase**) is a subdivision of the development process and represents the state of the product under development, e.g. planning, problem definition, conceptual design, detail design, etc. (see Figure 2.21).
- **Activities** are subdivisions of stages and relate to specific tasks that need to be performed e.g. analysing, synthesising, evaluating, etc.
- A **design strategy** is defined as the sequence in which stages and activities are planned or executed.

Designing is a socially-mediated and interdisciplinary activity performed by humans (Shah et al. 2004). It is typically carried out in a business context and involves almost all functions of a company, although three functions in particular are seen to be central to the process: marketing, design and manufacturing (Ulrich & Eppinger 2003).

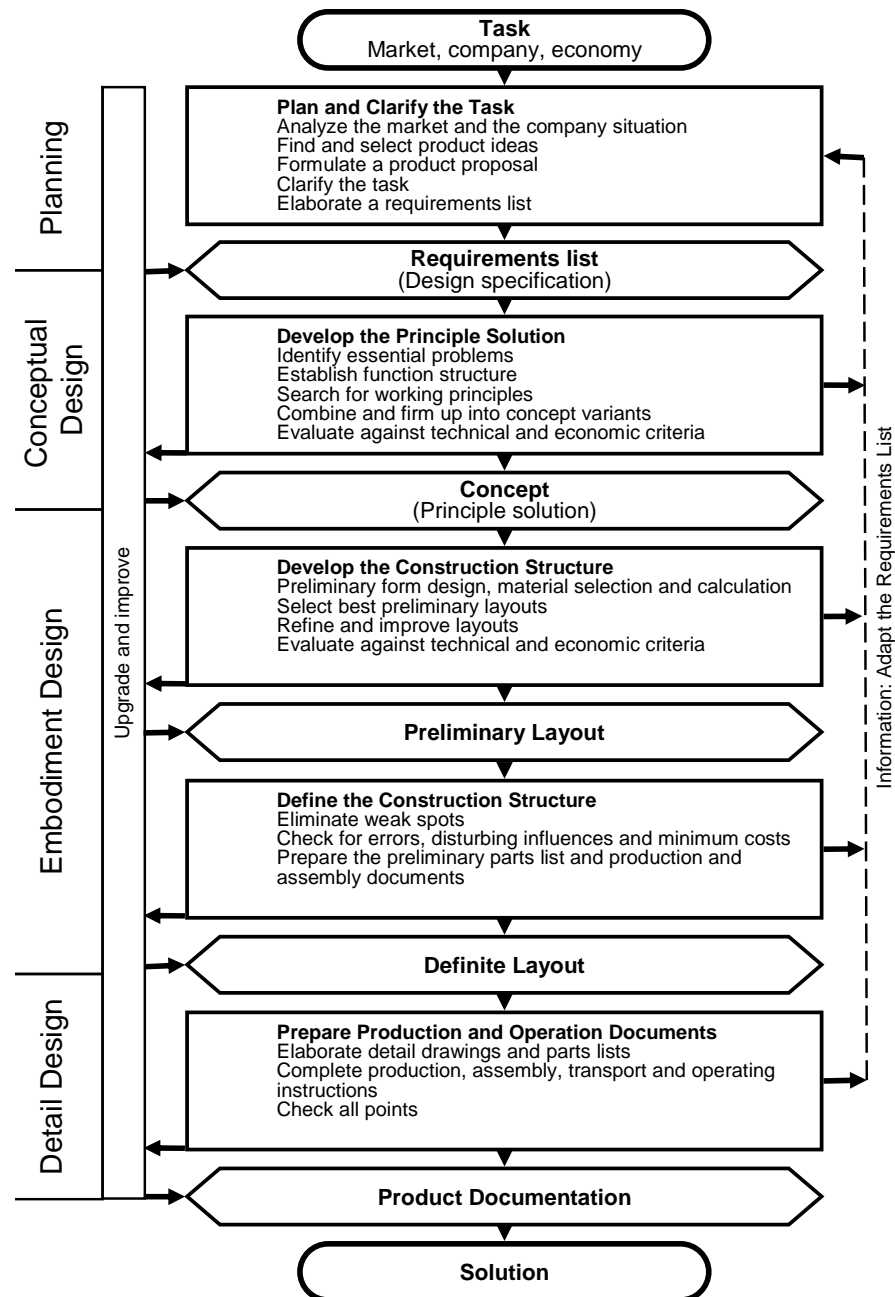


Figure 2.21 A systematic design procedure by Pahl and Beitz (1996).

The previous section demonstrated that the design object with PSS is expanded to include new dimensions of design, such as redefining the value proposition; product life cycle; activity modelling cycle; and the actor network. This section investigates what happens to the design process when the design object is not just technological artefacts, but integrated solutions that include intangible services. First, an overview is given of the different levels of design that occur in an organisation. Then design process models that have been proposed are scrutinised, starting with the product-based models, then the service-oriented models, and finally the latest design process models that have been suggested for PSS.

* FOUR MODELS OF DESIGN

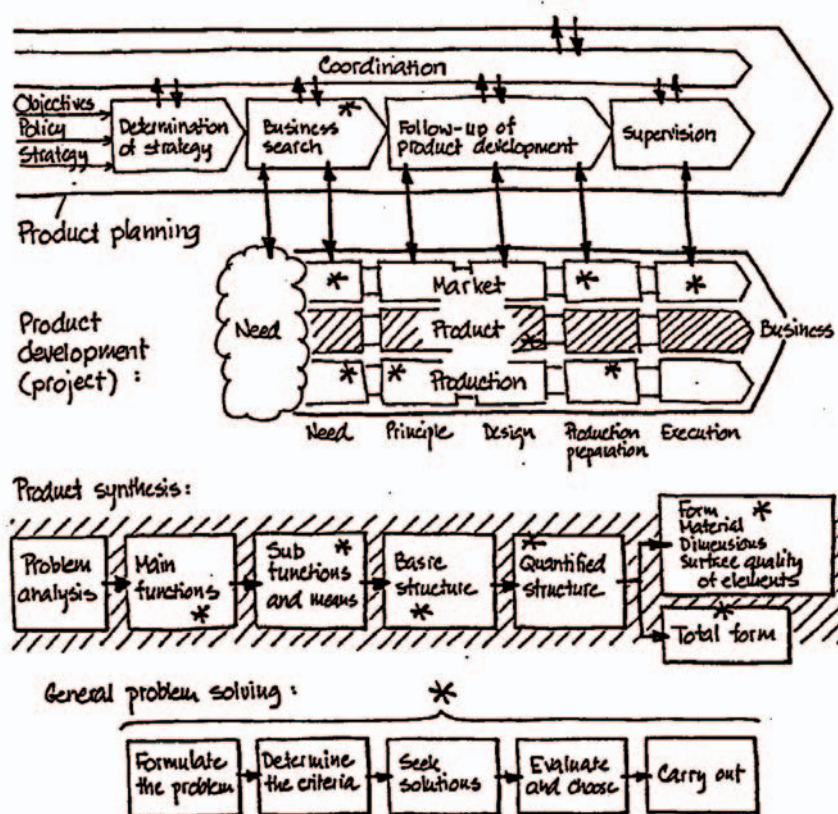


Figure 2.22 The four patterns of design in product development (Andreasen & Hein 2000).

2.5.1 A hierarchical model of designing

Engineering Design literature provides two types of models for designing: *descriptive* and *prescriptive* models (Blessing 1996). Descriptive models attempt to portray how design actually happens, whilst prescriptive models suggest processes for how effective and efficient design should be performed. Using prescriptive models, Andreasen and Hein (2000) lists four patterns to describe different design processes in product development (Figure 2.22):

1. *product planning* related to the company and business strategy
2. *product development* related to the development project
3. *product synthesis* related to the technical product
4. *general problem solving* related to the designer and basic design activities

Product Planning

Product planning is the basis for development of business and is concerned with the formulation of business and development strategies; business search; selection and initiation of development projects; management of resources; and the co-ordination and supervision of projects (Andreasen & Hein 2000). The portfolio of development projects covers a variety of different types of projects: pre-business R&D (e.g.

technology development, business searching, development of design methods and tools, etc.); innovative projects (e.g. development of new products, variants, architectures or modules); and maintenance projects (e.g. facelifts, cost reduction, re-design, etc.) (Andreasen et al. 1989). Product planning ensures that the company's development activities are coordinated with each other and in line with the company's business strategy and mission (see Figure 2.23). This aspect of design will be dealt with further in the next section.

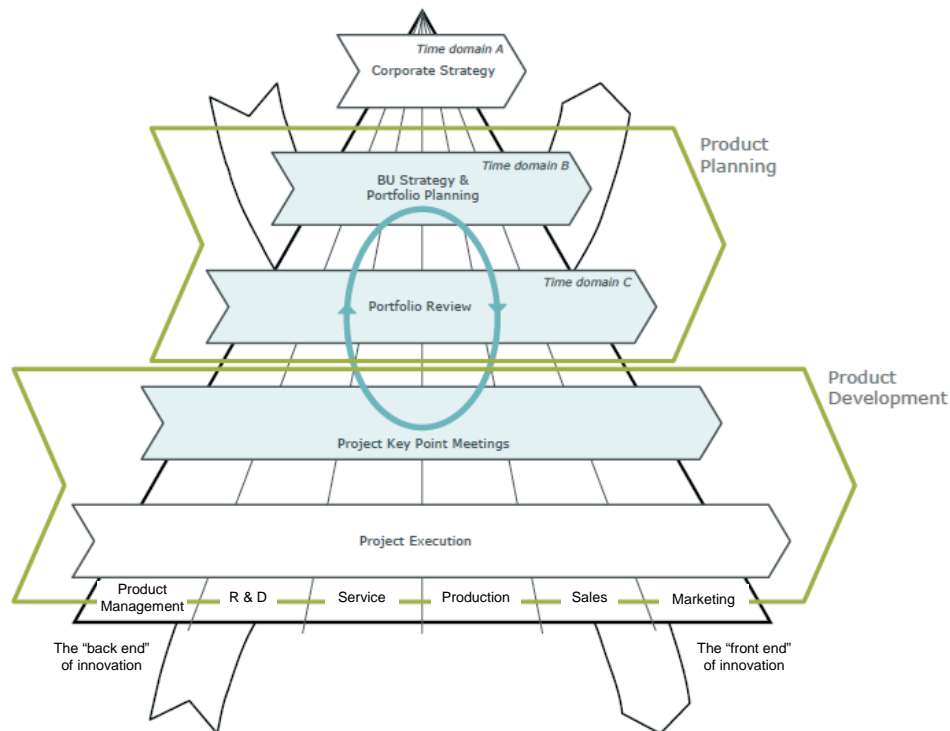


Figure 2.23 A model for portfolio management showing how corporate strategy, business unit strategy, portfolio review and key point meetings in individual projects relate to each other. Notice how the processes elapse in each their own time domain and rhythm (Larsson 2007).

Product Development

Product development includes all the activities in a company that lead to the generation of business: market research; development; establishment of production and sales; and on-going production and sales (see Figure 2.24). The product development process is multi-disciplinary and draws upon different disciplines and resources in and outside the company. Current prescriptive models of product development divide the process into stages that are initiated and concluded with 'gates'. Each stage consists of a range of development tasks that need to be performed and aligned with each other. In general three main stages of the design process are distinguished (Blessing 1996; Pahl & Beitz 1996):

- **Problem definition stage** based on an identification of a need, a problem definition and set of requirements is specified.

- **Conceptual stage**, during this phase the essential ideas and principles to how the need can be fulfilled are sought and combined into a total solution.
- **Detail design** is completed when a full product description is specified.

* INTEGRATED PRODUCT DEVELOPMENT

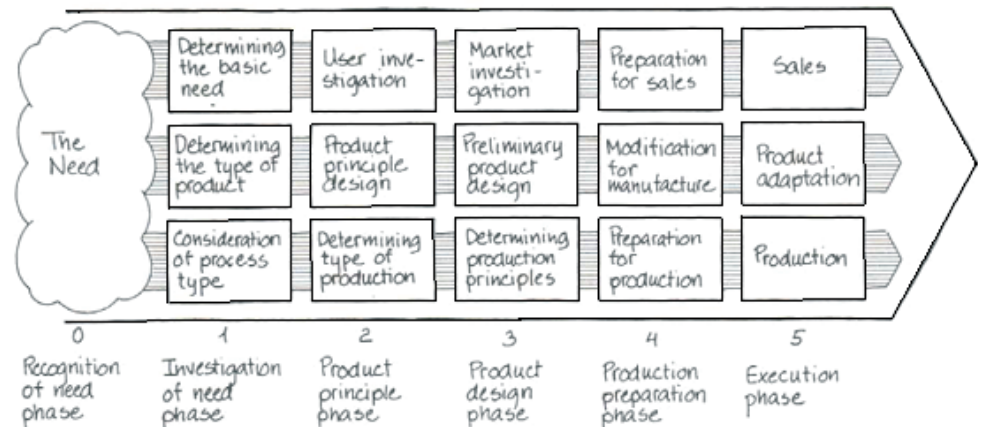


Figure 2.24 Andreasen and Hein's "Integrated Product Development" model showing the various stages of development and the parallel execution of tasks related to marketing, product design and production (Andreasen & Hein 2000).

At each gate the project group and management in the company can evaluate the feasibility of the project at various critical points in time. At the gates it is possible to terminate poor performing projects at an early stage. Stage/gate product development models have had a great impact on the practical management and organisation of the development task, increasing the chances for business success through the promotion of clarity, eased planning ability, reduction of risk and allowance of greater control over the development process (Ulrich & Eppinger 2003).

Product Synthesis

Product synthesis is concerned with the technical design of the product from problem analysis to fully specified solution (Pahl & Beitz 1996). This is typically what is referred to as product design or engineering design (Marxt & Hacklin 2005). The activities in product synthesis involve understanding the desired properties (criteria/specifications/requirements) of the technical system and then determining the characteristics that will realise these properties. For mechanical systems the characteristics that need to be determined are structure, form, material, dimensions and surface quality. Tjalve's prescriptive model (1979) of product synthesis that is shown in Figure 2.25, builds upon the *Theory of Technical Systems*, the *Theory of Properties* and the *Theory of Domains* discussed in the previous section. The product synthesis model involves solving tasks at various levels of detail and concretisation of the final product, starting from abstract functions and working towards concrete details of each design element. The individual tasks in product

synthesis depend on what needs to be designed, or in other words, the design object. Much of the Engineering Design literature has been based on physical technological artefacts and therefore it is unclear what synthesis models look like for other design objects, such as services. For example, a mechanical product is defined by the structure of the whole product as well as the material, dimensions, tolerances and surface quality of each its individual elements.

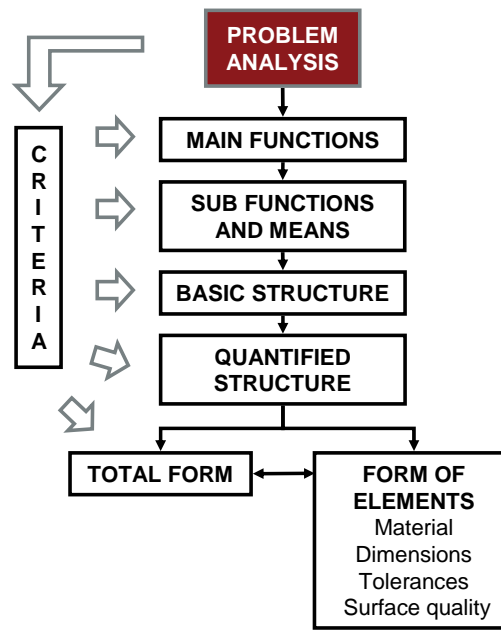


Figure 2.25 Tjåvle's model for product synthesis (1979) that prescribes a gradual creation of a technical system from a defined problem to a fully specified solution. The model emphasises the different levels (or domains) of design that the designer should explore before detailing the design object.

General Problem Solving

Problem solving is a general and elementary activity in all design processes. It is a creative human task involving analysis, synthesis and evaluation (Pahl & Beitz 1996; Blanchard & Fabrycky 1998). Theories of general problem solving are based on observations of how humans think and solve problems. Designers often decompose problems into manageable sub-problems, solving each and then assembling the solutions into a total solution (Pahl & Beitz 1996). As problem solving is a general process, it can be applied to any design process regardless of the nature of the design object. However designers should be aware that the decomposition of problems ('*reductionism*') should always be balanced with a systems approach and acknowledge the interrelated parts ('*expansionism*') (Blanchard & Fabrycky 1998).



Figure 2.26 A model showing the basic steps of general problem solving (Blanchard & Fabrycky 1998).

Although feedback loops are typically always present in all prescriptive design models, they all propose certain strategies for which order to perform each stage and activity (Blessing 1996):

- Stepwise
- Cyclic
- Decomposing
- Iterative
- Abstracting/concretising

Which strategy should be used depends on the design task, and is usually only provided as a guideline for designers to consider. During the planning of the design process, designers should clarify the dependencies between the many tasks and activities in the project by determining whether they are sequential, parallel or coupled (Ulrich & Eppinger 2003).

2.5.2 Designing products

The first scientific studies on the design process were based on mechanical engineering (Andreasen 2003). Although design process models have since been adapted to other application areas, a very mechanical product-oriented view of designing is still the most dominant in literature as well as in companies. This is for example the case of *Systems Engineering*, which emerged as a general engineering design discipline concerned with complex technical systems (Blanchard & Fabrycky 1998). Although Systems Engineering does encompass a life cycle approach and all the elements of PSS (see Figure 2.27), the approach to design is very dominated by its product-oriented and technical focus. This section will revise the state-of-the-art in product development models and identify the elements that are relevant to service development and PSS development.

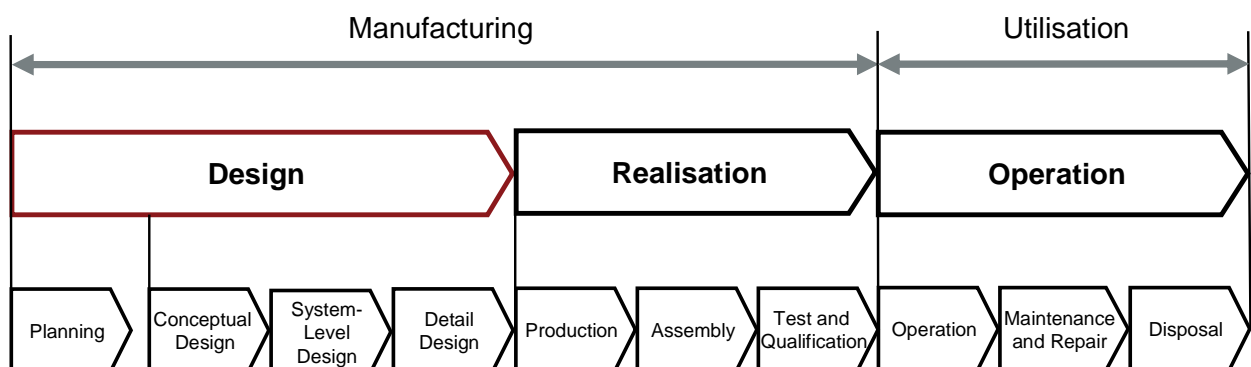


Figure 2.27 A general life phase model of technical systems after Blanchard and Fabrycky (1998). The design phase precedes realisation and operation. Manufacturing is traditionally the responsibility of companies and utilisation is traditionally a customer/user responsibility.

Integrated Product Development

Integrated Product Development (Andreasen & Hein 2000) is a prescriptive development model that provides a systematic approach for companies to structure their development task by creating overlap and interaction between activities in order to improve the overall product development performance (see Figure 2.24). Integrated Product Development (IPD) is characterised by a concurrent design approach in which multidisciplinary teams cooperate their activities both vertically and horizontally in the organisation. In order to achieve the benefits of integration, IPD approaches require that the objectives of the development project are complete and well defined. Consequently, understanding and identifying customer needs and demands at an early stage of the project is vital for the success of the project. In IPD models, the outline of future phases are drawn up and a terminology is created to facilitate communication across projects. This enables actors to understand their roles and responsibilities contributing to integration and concurrency in the development project.

Although IPD (also known as *Concurrent Engineering*) models have been heavily adopted by industry, they have been criticised on various aspects, such as the risk of the development project being built on the wrong assumptions, limiting innovation in the company and hindering the involvement of customers (Engwall 2003). A further limitation of IPD is that it no longer fits ideally to many industries' actual product development activities (McAloone & Robotham 1999). Some of the areas that were not addressed in IPD and similar models at the time they were introduced in the 1980s are life cycle oriented design; the performance of the activities the product is part of (e.g. total cost of ownership, quality, environmental issues); product structuring; the integration of other technical discipline (e.g. mechatronics); the role of IT in the development process; user-orientation; and globalisation (Andreasen & Hein 2000). The lack of these issues become apparent with PSS development as shall be seen in the following.

Life Cycle Oriented Design

All products go through a cycle of different phases throughout their "life": raw material extraction, manufacturing, use and disposal, as well as the transportation between and in each phase (Wenzel et al. 1997). During its life a product interacts with many different people (actors) in different contexts (life phase systems) – see Figure 2.28. Traditionally product development has focused on the performance of the product for a certain task and purpose, and not the total system the product becomes part of (Blanchard & Fabrycky 1998). Life cycle oriented design requires the designer to consciously consider the performance of the product in relation to the totality of the product's life cycle and all involved stakeholders (McAloone & Robotham 1999).

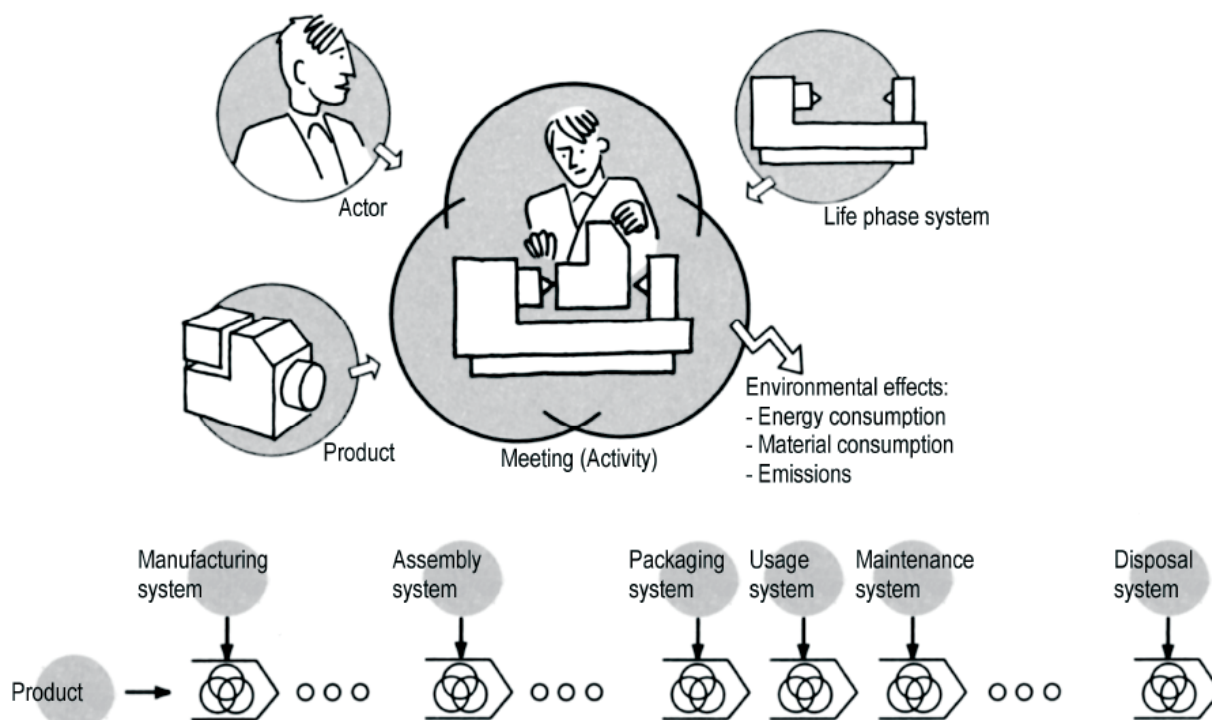


Figure 2.28 A life cycle oriented design approach considers the actors and life phase systems that the product encounters throughout its life (Hansen 1997). It is only during these meetings that the actual effects of a product can be observed.

Theory of Dispositions

An essential understanding for *Life Cycle Oriented Design* is the *Theory of Dispositions* (Olesen 1992) that defines the relation between the design process and life phase activities. A disposition is a “*part of a decision taken within one functional area that affects the type, content, efficiency or progress of activities within other functional areas.*” The theory explains the influence and therefore also the responsibility that designers have when decisions are made. It is fundamental for all designers to understand the effects a product has throughout its life and how they are caused. This becomes even more critical with PSS when companies take upon more responsibility for use and disposal phases of their products.

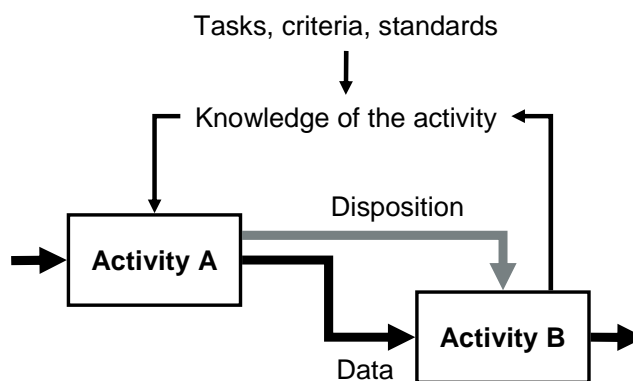


Figure 2.29 A general model of a disposition between two activities - after Olesen (1992). Disposition mechanisms are crucial to understand in product development, as decisions made during the design process determine the effects of an activity later in a product's life.

Dispositional thinking implies that products and product life phase systems should be designed in consideration of each other to ensure the desired properties and benefits of the system. Olesen (1992) suggests that the product and its life phase systems should be developed simultaneously (see also Figure 2.15). This fits well with the aforementioned approach of *Service Engineering* (Tomiyaama 2005) but it is not clear how the development activities for service delivery systems should be organised and coordinated with product development.

Design for X

In the field of Engineering Design a series of approaches dealing with specific design goals have been labelled '*Design for X*' methodologies (Blanchard & Fabrycky 1998). These methodologies (the most common being *Design for Manufacturability*, *Design for Assembly*, *Design for Quality* and *Design for Cost*) are applied during the design process in order to achieve solutions with certain desired properties (Hubka & Eder 1988). The 'X' in DfX may represent different life phase systems that are sought to be optimised (e.g. manufacturing, assembly, configuration, disassembly, etc.), or properties which the product is supposed to excel in during any of the life phase systems it encounters (e.g. cost, quality, reliability, flexibility, environment, etc.). DfX methodologies are synthesis activities in which structural characteristics of a product and its later life phase systems are matched to each other. This is done to achieve desired product properties in accordance with perceived qualities by relevant stakeholders (Andreasen & Hein 1998). DfX rules are experience based collections of dispositional mechanisms that exist between the design phase and later life phase systems. The design of PSS demands simultaneous application of multiple DfX approaches even though they can partly be in contradiction to one another (Meerkamm 1994). In relation to the service aspects of products, the following DfX approaches are of particular interest: *Design for Environment* (or *Ecodesign*), *Design for Maintainability/Serviceability* and *Design for Supportability*.

Ecodesign (Design for Environment)

In the 1990s a lot of attention was put into developing methods to support the design of products with low environmental impact. These methods became known as *Ecodesign* or *Design for Environment* (Brezet et al. 2001). Core to understanding a product's environmental impact is the perspective of the total life cycle of the product from 'cradle to grave' (i.e. raw material extraction, production, transportation, use and ultimately disposal). *Life Cycle Assessment (LCA)* became the most accepted method of analysing and assessing the environmental life cycle impacts of products and services. Whereas LCA methodologies are analytical in nature, Ecodesign deals with the causal relationship between the choices made during the design process and the environmental effects that become apparent during the product's life

cycle phases. The understanding of the connection between a product's design phase and its life cycle is core to developing sustainable solutions.

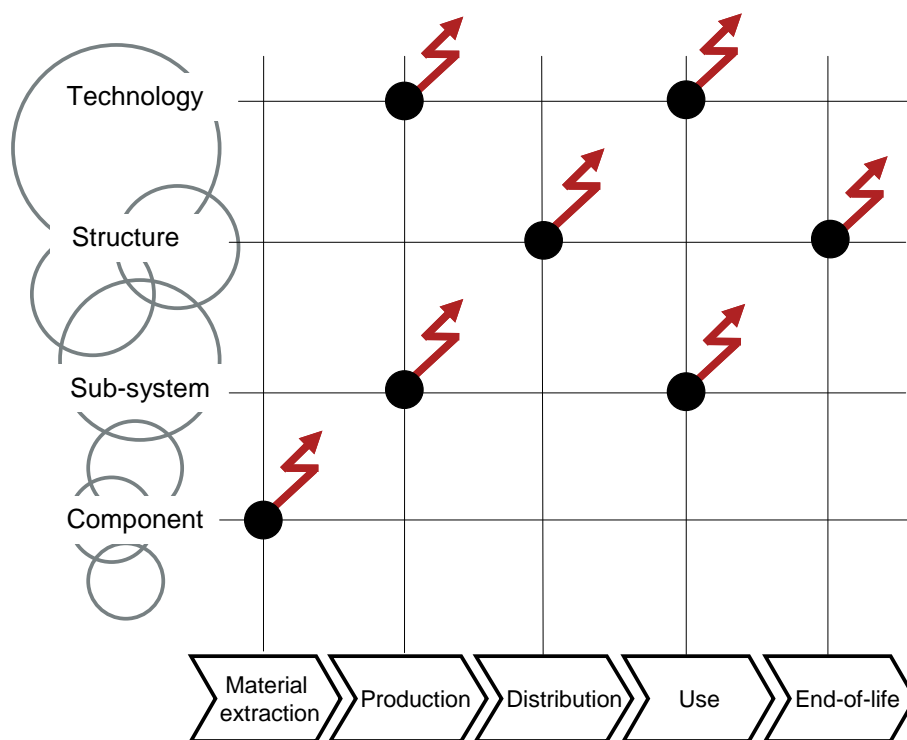


Figure 2.30 A product's environmental impacts can be mapped in relation to different product levels and where in the product's life cycle the impacts occur (Olesen et al. 1996). From this product developers can effectively seek solutions at each product level to minimise the overall environmental impact of the product.

Based on LCA methodologies, product developers use Ecodesign to identify the aspects of the product that contribute with the greatest environmental impacts and determine where their greatest improvement potential is. Changes to the product are then suggested at different levels of detailing (Figure 2.30). Starting at the lowest levels, this could be selecting other materials or production processes for components or at a higher level redesigning sub-systems or the total structure of the product. It could also be a much more fundamental change and choosing a different technology that provides the same product functionality more efficiently. Often the potential for environmental improvement increases with the ability to change the higher conceptual levels of a product. Although Ecodesign aims to improve the 'fit' of the product to its actors and life phase systems, it is generally limited to only making changes on the product itself in most companies.

Design for Maintainability/Serviceability

These approaches cover the support of repair and maintenance activities of the product. Moss (1985) defined Design for Maintainability as *"an element of product design concerned with assuring the ability of the product to*

perform satisfactorily can be sustained throughout its intended useful life span with minimum expenditure of money and effort." Here the focus is on the ease of repair by considering repair properties during the design of the product. Design principles such as (Design for) reliability, modularisation and good diagnostic systems are common practices. Tjiparuro and Thompson (2004) suggest the most significant design axioms are: simplicity, part features, operating environment, part identification and assembly/disassembly principles. Modularisation is an example of where a *Design for Assembly* principle is a good match with Design for Maintainability. To assure safe operation and reliable technical installations, a number of different analysis methods and tools exist, e.g. *Failure Mode and Effects Analysis (FMEA)*, *Fault Tree Analysis (FTA)*, etc. (Blanchard & Fabrycky 1998). These analysis methods are well developed today. Together with monitoring systems, they allow maintenance activities to be proactively employed to prevent unnecessary downtime and optimal performance (Lee 2003).

The term *maintainability* and *serviceability* (Blanchard & Fabrycky 1998) seem to be almost synonymous, with serviceability possibly encompassing more design criteria in order to include aspects of the delivery system as well, such as part availability and online or self-diagnostic systems. General Motors design teams have used a *Serviceability Task Evaluation Matrix (STEM)* that includes criteria such as estimated repair and maintenance time, part cost, diagnosis time, tool requirements, technician training requirements and part availability (Lynch 1995). Based on its *Design for Manufacture and Assembly (DFMA)* software, the consultancy firm Boothroyd Dewhurst Inc. (Editorial 1994)), has also introduced a '*Design for Service*' application (also here service means repair and maintenance). The application calculates a serviceability index based on *Design for Assembly* information and gives an estimate on service time and costs. A product's properties regarding its ease of taking apart components and putting them together again are of course also relevant properties for *Design for Disassembly* as well as *Design for Recyclability*.

Elaborating the aspects of full life cycle support, the *Design of Maintainability* also includes strategies regarding the planned service frequency and needed competence of technicians (Lele 1997). Takata et al. (2004) proposed a framework for life cycle maintenance that includes the following activities (see Figure 2.31):

1. Maintainability design
2. Maintenance strategy planning
3. Maintenance task control
4. Evaluation of maintenance results
5. Improvement of maintenance and products
6. Dismantling planning and execution

The key issues to be considered in this framework are:

- Adaptation to various changes during the life cycle
- Continuous improvement of products
- Integration of maintenance information

Although these issues are emphasised, no practical examples or systematic methodological approaches are offered on how this may be achieved in design. Nonetheless, Design for Maintainability and Serviceability approaches represent the most basic steps to PSS for a manufacturing company.

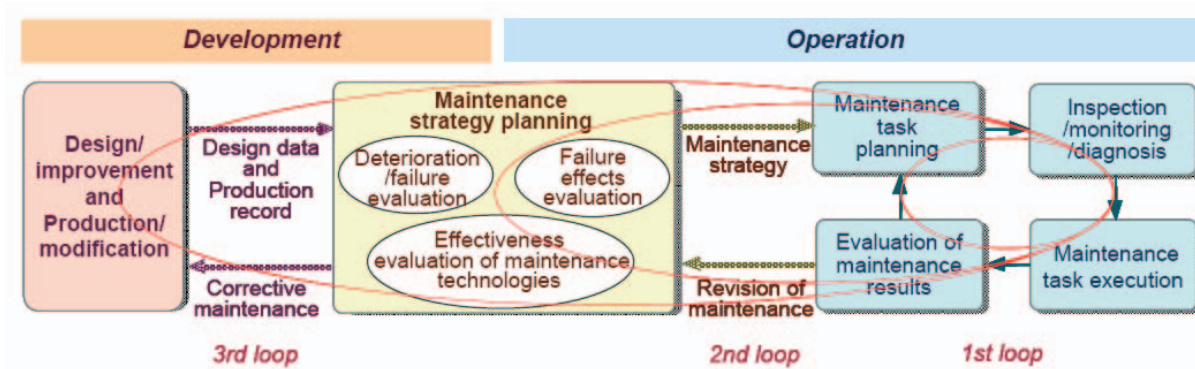


Figure 2.31 Framework for life cycle management as proposed by Takata et al. (2004).

Design for Supportability

Goffin (2000) uses the term supportability to cover all product (after sales) supporting activities, covering both maintenance and repair, but also installation, training, spare parts and auxiliary products, documentation, availability, customer consultancy and warranty schemes. Compared to Design for Maintainability it seems the rationale for applying Design for Supportability methods are not just about cost reduction, but just as much about revenue generation. Goffin (2000) lists several factors that typically prevent companies from developing products that are easy and efficient to support. These are:

- Support requirements are considered too late in the product development cycle.
- Field support engineers and managers, who know support problems first-hand, do not have the opportunity to influence product designs.
- Decisions taken to lower production costs may make support more difficult or expensive.
- Product features often take priority over product support considerations.

In the context of PSS where business strategies are focused on supporting product life and customer activities, the factors mentioned above should therefore be given higher priority and be central for the development team's objectives. As Design for Supportability covers more activities than just repair and maintenance, so do the design

criteria for methodology (see Figure 2.32). These include focusing on parameters such as reliability (measured in *Mean Time To Repair (MTTR)* and *Mean Time Before Failure (MTBF)*), availability (of spare parts and personnel), serviceability, usability and installability (Goffin 2000). Design for Supportability is an extension of Design for Maintainability/Serviceability with the potential of greater value to the customer. At the same time it requires more resources and competencies that a traditional manufacturer would not necessarily have at their disposal. The options are to either build up competences and learn how to manage support activities over time; or alternatively, outsource support related activities to external partners.

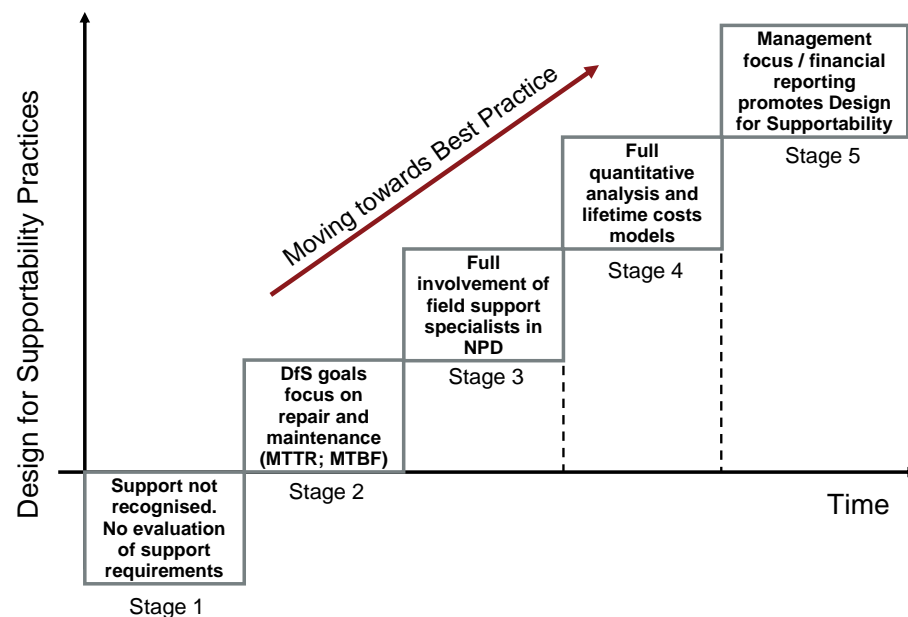


Figure 2.32 The stages companies typically move through from recognising the importance of product support to practicing effective Design for Supportability (Goffin 2000).

A key difference with PSS approaches compared to the above mentioned product-oriented approaches is that the company plays a key part during the entire product life period. The company takes on the responsibility of the physical products during its use, maintenance and disposal phases. This will naturally motivate companies to focus more on the performance of the activities the product becomes part of than the technical product itself. Depending on what universal virtue (Olesen 1992) is critical in each activity DfX approaches need to be elaborated to include the expansion of the design object in PSS.

2.5.3 Designing services

Compared to the research literature in product development, there is sparse literature regarding research in new service development (NSD) (Alam & Perry 2002). Models for NSD are often derived from existing models of product development (Johnes & Storey 1998; Brezet et al. 2001), but researchers in service development emphasise that due to the

difference that products are ‘things’ and services are ‘processes’, service development is different in nature to product development (Shostack 1982). For example, in service development there is a clear distinction between what is offered to the customer (service concept), how it is delivered (service process) and what resources need to be in place to deliver it (service system), see Figure 2.33.

Typically researchers in service design and development are found in the area of marketing and the reason for the claimed differences between product and service development is more to do with the differences between industry sectors (e.g. manufacturing, financial, insurance, health care, etc.) than generic product or service characteristics (see discussion in section 2.3). So far few studies have been conducted on service development in manufacturing companies (Gebauer 2008).



Figure 2.33 Based on the service prerequisite model (see Figure 2.13) Edvardsson and Olsson (1996) distinguish between three types of development of services (unlike Integrated Product Development, the time required and dependency relations for each development process is different).

Prescriptive service development models have been offered by a number of researchers. These models build upon product development models with the same general sequence of stages and activities, but authors claim that the importance and manner in which certain activities are carried out are different in service development compared with product development (Scheuing & Johnson 1989; Bitran & Pedrosa 1998; Johne & Storey 1998). The differences often cited are that service development involves:

- Deeper understanding of the *customer and customer activities* (Vandermerwe 1993)
- The development of a *value proposition and a service operations concept* (Scheuing & Johnson 1989)
- The *involvement of customers* in both the development and delivery of services (Alam & Perry 2002; Menor et al. 2002; Matthing et al. 2004)
- The *involvement and training of front-line personnel* (instead of production) (Johne & Storey 1998; Alam & Perry 2002)
- Difficulty of *describing, evaluating and testing service concepts* (Johne & Storey 1998)
- *Post launch evaluation and modification* (Scheuing & Johnson 1989)

- *Customer-oriented personnel as designers* and not engineers (Brezet et al. 2001)
- *Softer design variables* (e.g. time, place, personnel instead of materials, dimensions, shape) (Brezet et al. 2001)

Similar to product development, several researchers have provided evidence that firms that adopted formal service development processes also had greater chances of success (de Brentani 1991; Martin Jr & Horne 1995). It is difficult to determine whether the differences between product and service development are due to the nature of the design object (product or service) or the company's perspective (product-oriented or service-oriented) of their value proposition.

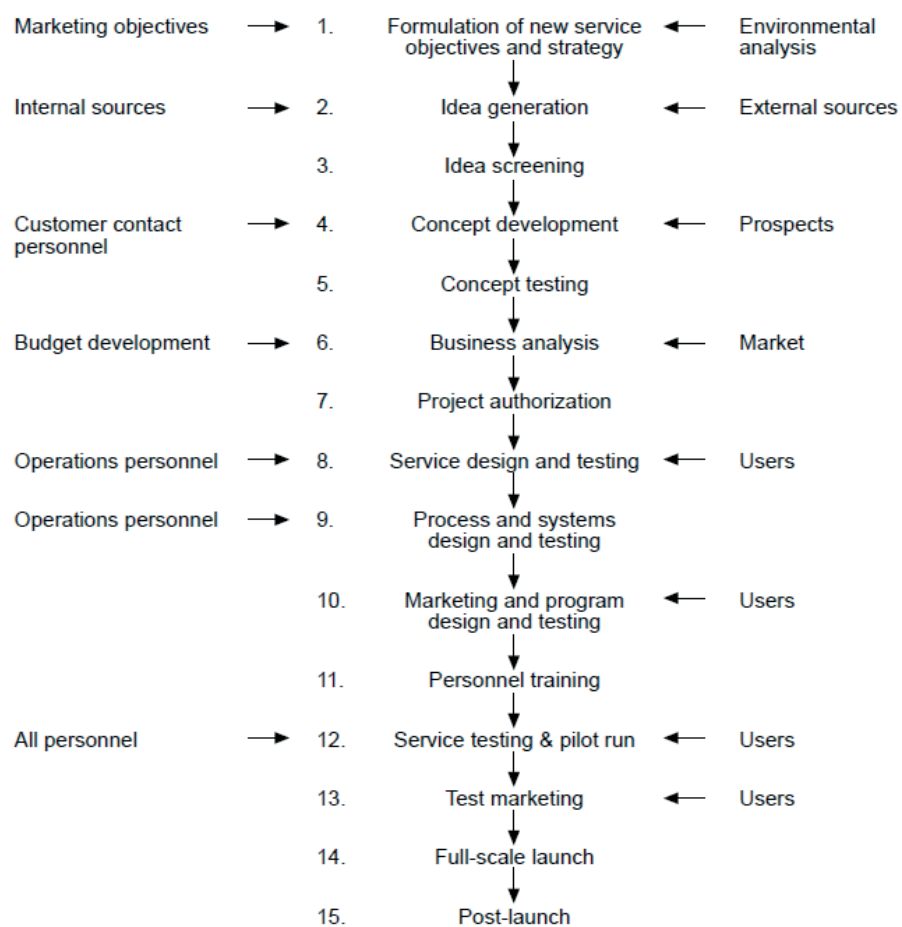


Figure 2.34 A normative process model for new service development process (Scheuing & Johnson 1989). Here a distinction is made between the design of the service and the design of the delivery process (step 9).

In recent years researchers in product development have emphasised the importance of user-centred design where the user is given extensive attention throughout the design process (Brandt 2001). This approach represents a more service-oriented approach to development. Traditionally manufacturing companies did not consider the customer's activities as a primary part of the value creation process, but merely as value extracting processes (Prahalad & Ramaswamy 2004). In order to

employ customers and stakeholders as resources, the company must establish activities in which customers and stakeholders are encouraged to participate in the development process (Martin Jr & Horne 1992; Alam & Perry 2002). For both products and services, the design task consists of determining the product's structural characteristics so that the desired properties may be attained. Weber et al. (2004) emphasise that "*the customer should be integrated into the development*" when considering PSS approaches as it is difficult to establish service characteristics without the customer's involvement.

Designers in service development tend to be focused on the customer's experience (Frei 2008). An important issue in service marketing is the attention to the difference between expected service and perceived service (Parasuraman et al. 1985) – also known as '*service quality gaps*'. The quality of services is typically based on customer satisfaction. Compared to product development, services better allow changes and modifications to be made once they have been launched. The focus on customer relationships and on-going need satisfaction are cited as being pivotal in service-oriented approaches (Johns 1999).

The past decade has seen the advent of professional service designers (Moritz 2005). Originally skilled in industrial design, product design or interaction design and often borrowing elements from anthropology and ethnography, these service designers use systematic tools and methods to design services, typically in service industries and the public sector. Some of the tools that have been proposed are:

- ***Service Ecology Map*** – a visualisation of a system of actors that form a service and the relationships between them. This is similar to the representation of Actor Network presented in section 2.4.3.
- ***Client Journey*** – all the interactions with a product, person, or space over a certain period of time. This is similar to Customer Activity Cycles and Service Blueprinting (see section 2.4.2) but goes much more into detail with the actual real time experience of the customer.
- ***Touch Points*** – individual tangibles or interactions that the end user or customer comes in contact with and thereby forms the totality of experience. Humans experience through their physical senses and touch points are the interfaces and evidence of services. Service touch points can be identified in Customer Activity Cycles.
- ***Service Prototyping*** or ***Experience Prototyping*** – a manner in which a service is tested by acting it out with simple props and thereby allowing the service experience to be quickly assessed.

Service design is still evolving in both companies and in research communities. Models, methodologies and tools are still being proposed and tested. Although the design processes of services are based on product development, they are characteristically much more customer-oriented, e.g. customer involvement and the focus on customer processes is much more prominent in the development and execution of services. In relation to PSS development, service development literature tends to be focused on customers, but overlooks the potential of synergetic effects when products and services are designed to complement each other.

2.5.4 Designing PSS

Over the past decade several research projects have focused on methods, methodologies and tools for the design and development of PSS (Brezet et al. 2001; Manzini et al. 2004; Tomiyama 2005; Morelli 2006; Tukker & Tischner 2006; Vezzoli 2007). Although a wide range of methods and tools were proposed, the academic rigour and research standard has been questioned (Mont & Tukker 2006; Tukker & Tischner 2006). The methodologies were typically developed in projects removed from manufacturing firms' actual development context or completely independent of industry. The results of these projects have yet to be verified (Baines et al. 2007).

As the researchers that proposed PSS design methodologies typically had a background in Ecodesign, the starting point for most development processes is a life cycle assessment (LCA) of existing products and/or services and exploration on how the same benefits (or in LCA terms the '*functional unit*') could be provided to customers (Vezzoli 2007). Especially when the use phase is identified as having the largest environmental impact, the methods emphasised analysis and understanding of user and use contexts. Here inspiration from anthropology, ethnography and socio-technical approaches was included in the development methods (Morelli 2003). Related to this is also the importance of building partnerships (or actor networks) where all actors are aligned and incentivised to ensure the most efficient use of resources (Manzini et al. 2004). These aspects lead to a more collaborative approach to design where multiple stakeholders along a product's life cycle all actively participate in the design process. One example of this is the increasing active role users play in the development of new or improved products and services in what has come to be known as user innovation (Hippel 2005).

The role of the designer would also change in PSS. Compared to product design, where value is mediated by the technical artefact, designers of PSS would have to develop skills in (Morelli 2006; Vezzoli 2007):

- The analysis of the *cultural, technical and social frames* of products and services

- The identification and analysis of *stakeholders and their relative social and cultural requirements* (actor network, see section 2.4.3)
- The analysis of *usage patterns*
- The envisioning of *alternative PSS scenarios and use cases*
- The synthesis and proposition of *new values for the service* and the translation of those values into concrete design actions.

Here a socio-cultural dimension to design is introduced. In order to make a radical change to the existing consolidated product-oriented approaches to providing value, the socio-cultural aspects of design need to be taken into consideration. PSS involve more than changes to technological and organisational dimensions, but also involves the mobilisation of actors and social groups in this process. At the same time it is seen as an opportunity for companies to turn to more socially responsible business practices.

A major endorsement of PSS is that the provision of products and services adapts according to the individual customer's needs. The objective of PSS development is therefore not a fully specified product or service, but a specification of a solution platform on which products and services can be continuously developed and customised (Manzini et al. 2004). In the *Solution Oriented Partnerships Methodological Framework* (Manzini et al. 2004) aims to establish alliances between partners based on specific contexts. Three dimensions (streams) are defined (see Figure 2.35):

- *partners* (the actors of the system);
- *contexts* (the user's/customer's situation); and
- *solutions* (the system of products and services) which each are first explored, and then solution platforms are developed.

	explore	develop	platform vision	explore	develop
partners	Solution Promoters	Platform Providers		Planned Providers	Solution Providers
contexts	Contexts-of-Use	Meta-Context-of-Use		Target Contexts-of-Use	Specific Contexts-of-Use
solutions	First Solution Ideas	Solution Platform Ideas		Proposed Solutions	Partner-Based Solutions

Figure 2.35 An example of a PSS design methodology proposed: *Solution Oriented Partnership Methodological Framework* (Manzini et al. 2004). The methodology specifies first a partner-based solution platform design process, then a customised and contextualised individual solution design process.

These dimensions correspond to the PSS design dimensions mentioned in section 2.4.3, but they lack to integrate product life cycle thinking in their approach. The framework is based on two development processes in sequence. First the development of a general solution platform, and then the development of specific and customised and contextualised PSS solutions. This is a manner of ensuring systematic development of industrialised solutions while still allowing flexibility to individual customers.

Another PSS design methodology is *Business Models for Inherently Sustainable System (BISS)* (Tukker & Tischner 2006). Here the proposed steps to PSS development are:

1. Definition of the current business model
2. Mapping out interests of all the involved actors
3. Identifying the economic and ecological inefficiencies
4. Generation of a new PSS that points towards sustainable business models
5. Definition of the new business model and the key contracts

Here it is particularly the actor network and business model that is in focus as the design object. The objective is to generate solutions that create and stimulate economic incentives and align all actors so they behave environmentally and socially responsibly. The methodology assumes that knowledge and understanding of product life and customer activities are implied.

Both Solution Oriented Partnerships and BISS were developed by research centres and companies in collaboration funded by EU. A lot of the research focused on the inter-institutional/organisational collaboration, but did not provide much guidance how it relates to the actual business context, processes and strategy of each partnering organisation.

From the business focused literature a number of observations are made about manufacturers developing integrated product/service solutions. Aurich and Fuchs (2004b) list three strategies to integrating product and service development (see Figure 2.36):

- ***Liability driven: Systematic product design + Intuitive service design.*** This describes the traditional situation for the majority of manufacturers. The development and manufacturing of products are the company's core competencies. Services are mainly liability oriented to guarantee product functions and their development is not systematic.
- ***Function driven: Systematic product design + Systematic service design.*** Based on a range of systematically developed products, a set of services are subsequently systematically developed to enhance the functionality of the products. Preventive maintenance is an example of this.

- **Use driven: Integrated design.** Products and services are developed in an integrated manner based on customer needs. Here the customer only pays for the performance of the PSS.

Each of the strategies represents different degrees of service-orientation and shows how the design processes and delivery (production) processes are related.

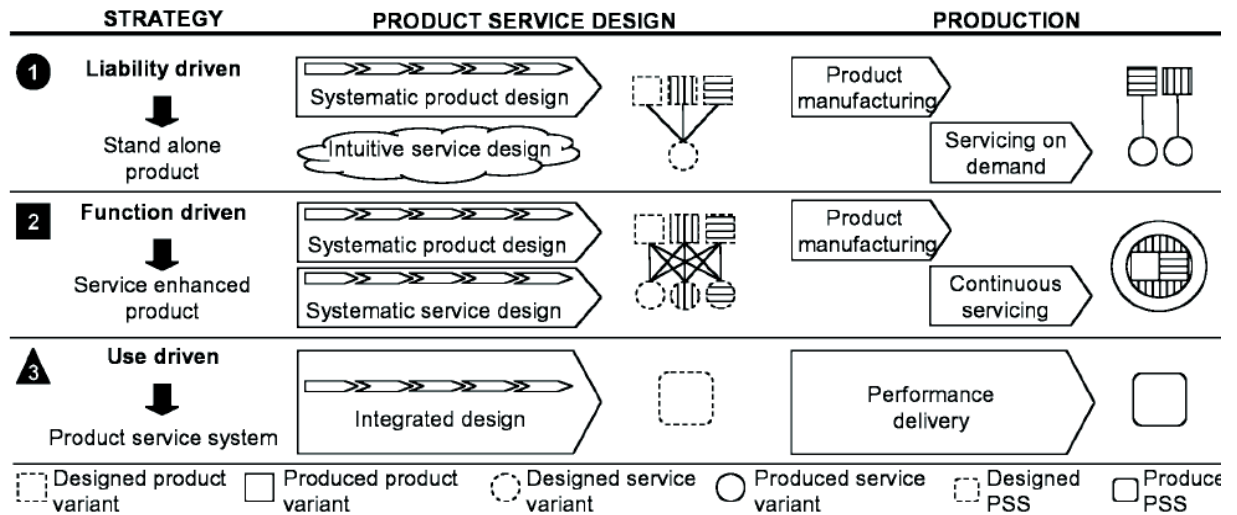


Figure 2.36 Three design strategies that lead to PSS (Aurich et al. 2004a).

According to Gebauer et al. (2008) there are different factors that are important to success in each of the above mentioned design strategies. For example, the presence of a service champion, the autonomy of employees, market testing and market research had actually counter effects on the success of innovation when product and service development was integrated, whilst they were beneficial when service development was a separated process.

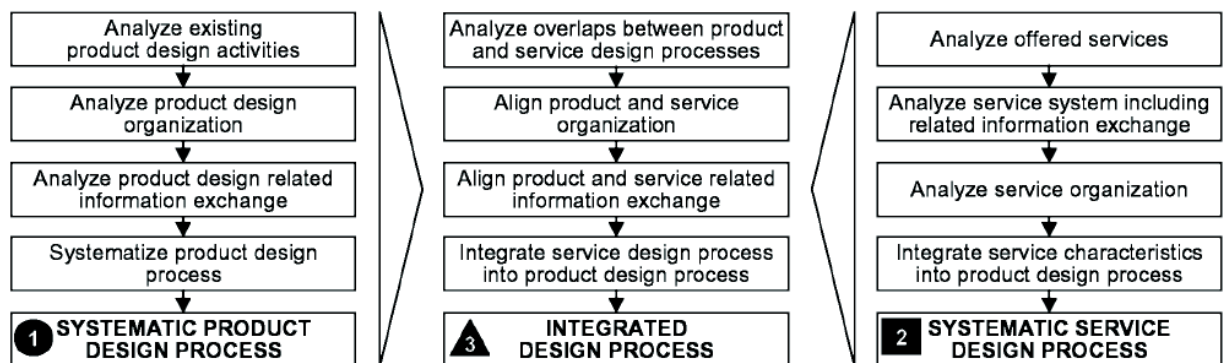


Figure 2.37 Aurich et al. (2004b) propose a systematic approach to integrating product and service design process.

Aurich et al. (2004a) further elaborate on what steps should be taken to relate service design to product design. They propose to start by analysing the existing product development process and then analysing the current technical services offered, the service organisation and

identifying service characteristics in the product design process (see Figure 2.37). Based on this the different design process, development organisations and information exchanges are then integrated.

As the development of services represents an establishment of new business for the manufacturing company, demand identification and feasibility analysis need to be undertaken in order to continue the process (this would also be the case if product development was not already established in the company) (see Figure 2.38).

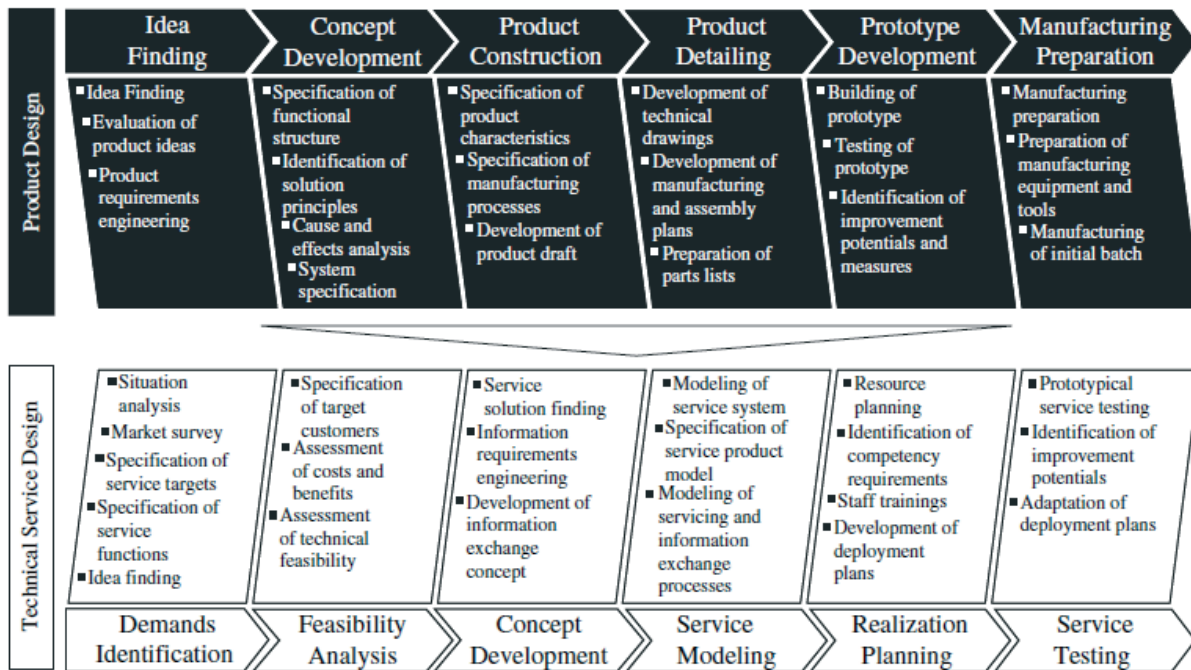


Figure 2.38 Systematic technical service design based on existing product design processes (Aurich et al. 2006).

Although Aurich et al. (2006) do recognise that several actors need to have a common understanding of the whole PSS, this does not manifest itself in their proposed model. The process model does not reveal when and how for example customers, service partners or suppliers are involved. An example of how customer involvement is addressed can be seen in Figure 2.39 (Cornet et al. 2001). By involving the customer in the development process from the start, a higher rate of success is ensured, but the challenge is to be able to offer customerised solutions without losing the efficiencies of systematic product development processes. Companies need to clearly define the role and responsibilities of customers when involving them in the development process. Likewise responsibilities and roles of partnering companies and suppliers must also be carefully considered. Here Solution-Oriented Partnerships points out that relationships and incentives have to be constantly nurtured in order to offer PSS (Manzini et al. 2004).

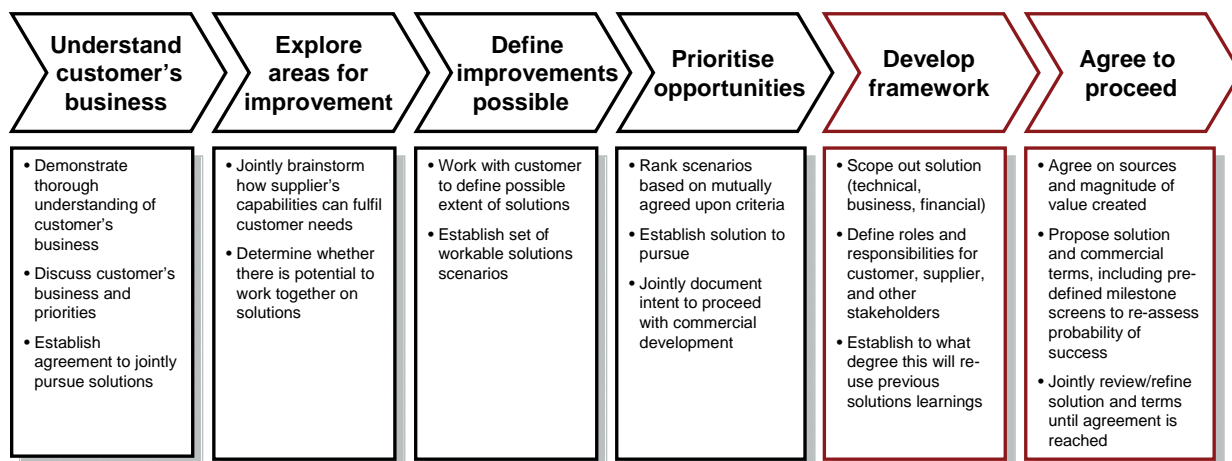


Figure 2.39 The development process for solutions involves close collaboration with customers (adapted from Cornet et al. 2001).

An important aspect of Aurich et al.'s (2004a) process model (Figure 2.37) is that the information exchange processes are considered early in the service development. A prerequisite for PSS design is the ability to gather, store and analyse data about products and customers that then can provide information on how to enhance the value of customer activities.

Today, manufacturing companies have two types of IT systems that attempt to cater for this, *Product Lifecycle Management (PLM)* systems and *Customer Relationship Management (CRM)* systems (Hicks et al. 2007). Each system has their own focus, PLM systems administer product specific data and information throughout its entire lifecycle, but as companies are rarely responsible for the use and disposal phases of their products, the gathering and processing of information here is rather poor. On the other hand CRM systems capture, store and analyse customer information and communication, but again not much information is obtained from the activities where the product is actually in use.

From a product development point of view, a systematic gathering of information of product use would be extremely valuable to the development of new products and services (see Figure 2.40). If a perpetual coupling of product and customer information during operation was possible, insights and knowledge could be gained to ensure that the customer's activities were continuously aligned with their customer's needs and behaviours. But for now the management, accessibility and relevance of knowledge to product developers and designers is still not well established. The ability to gather, store and analyse data about products and customers so that can then provide information on how to enhance the value of their customer activities, would seem a prerequisite for the development of PSS.

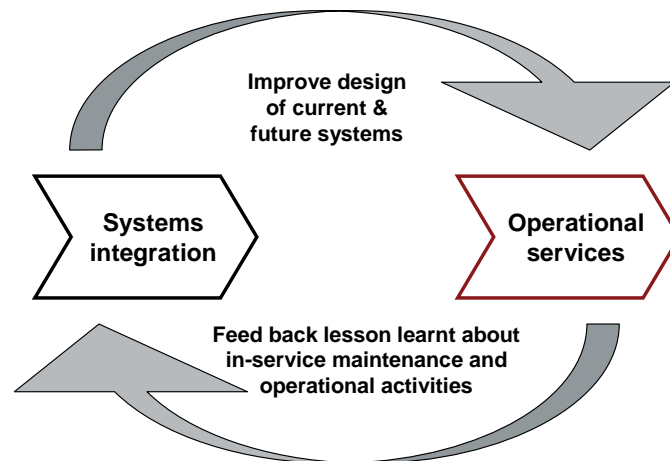


Figure 2.40 Ensuring information feedback from systems in operation are vital for improving the design of current and new systems in PSS (Davies 2004).

Figure 2.41 illustrates the variety of development approaches found in literature that integrate products and services. Although presented in rings, there is no sharp distinction between these types of services. The transition from product-orientation to customer-orientation is fluid. A manufacturing firm may offer these services in any constellation. The illustration below is merely offered as an overview of which development strategy would be relevant to consider when designing these different types of service.

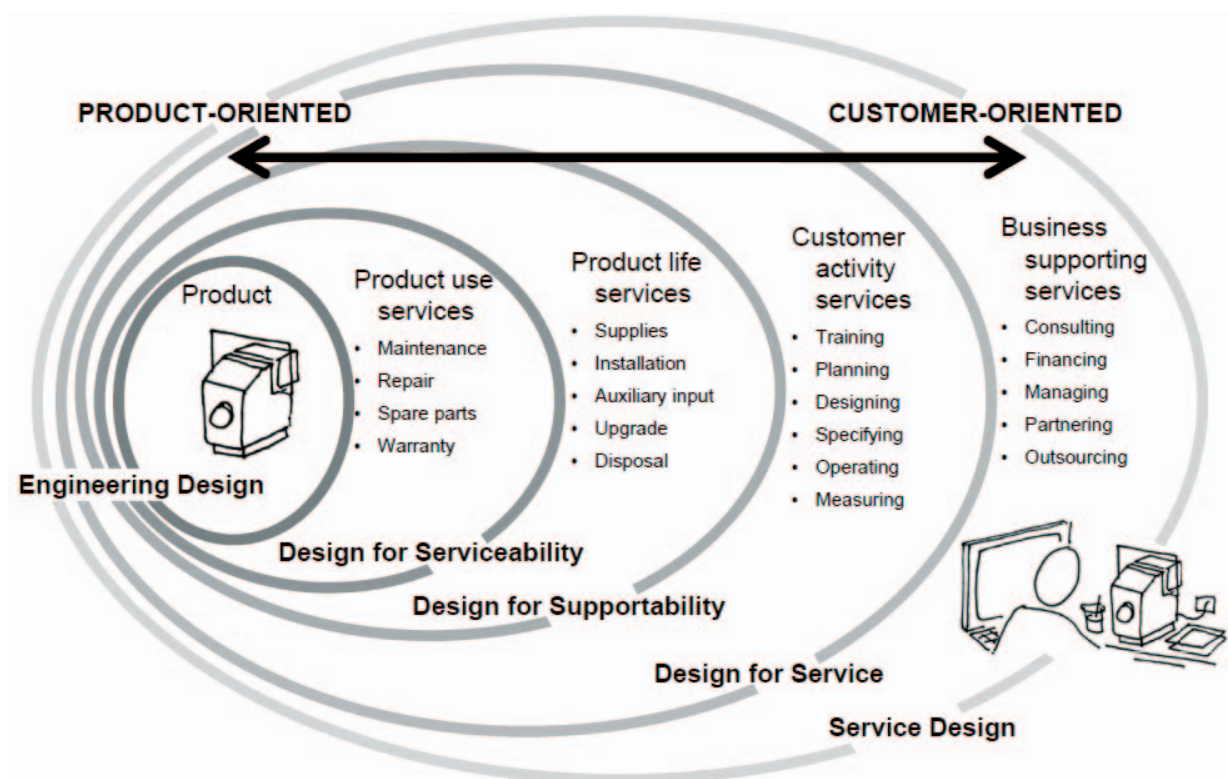


Figure 2.41 The span of service-oriented development methods offered by literature in relation to different types of services (Tan et al. 2009).

2.5.5 Summing up – design processes

The result of the literature study of methodical approaches to product and service design contributes to the understanding of PSS development. In product-oriented development models the process ends with a full product description or the realisation of production and sales. Service-oriented development models are more customer-oriented and often involve the customers in both the design and execution phases.

With PSS approaches the development task is expanded in time so that it also encompasses the use phase to ensure continuous development that is aligned with the customer's activities. Fundamentally the difference between PSS development in relation to traditional product development is that:

- the *physical product is supported and enhanced throughout the customer's activities* by the providing company (the business relationship with the customer may spread over several product upgrades and generations).
- the *value creation is in the resulting activity* where both the physical product, supporting services and the customer all play a vital role (the perception of value is beyond the physical product itself).
- the *customer's activities are part of the value creation process* and the providing company must interact closely with the customer throughout the life phases.

In general the design models in product and service development share very common characteristics, but while product-oriented design processes focus on technical functions and transformations, service-oriented design processes focus on the activities involving the customer and the co-creation of value.

The next section will look at what literature has to offer on how companies make the shift from product orientation to a more integrated PSS approach.

2.6 Strategic management

Product development activities are a vital part of a manufacturing company's value creating activities, but its performance is interdependent on the other activities in the organisation and the overall business strategy (Andreasen et al. 1989). In this section the linkages between a company's development activities and the rest of the organisation are investigated. These linkages are both vertical in the organisation, i.e. the connection between strategic, tactical and operational, as well as horizontal, i.e. coordination and integration with other functions, i.e. sales, production, service operations, etc. PSS are

considered to be a shift in business focus, so the focus in the following is on the transition from product to service-orientation.

2.6.1 Business strategy

PSS are seen as an innovation strategy or business model for companies used to manufacturing and selling products (Tukker & Tischner 2006). Business strategies are coordinated plans for how a company can establish a competitive position in the market place. There are many different schools of thought regarding the formulation of strategy (Mintzberg & Lampel 1999), where one of them is based on contingency theory which asserts that the performance of an organisation depends on how well the fit is between the external environment, strategy and the organisation.

In this thesis the focus is on service-orientation in manufacturing firms. An underlying assumption with PSS is that manufacturing firms can capitalise on their experience and knowledge of their products and use this to create linkages to service activities that would not be accessible for players on the market (Mathieu 2001b). However, a manufacturer will very rarely abandon its current business completely and establish itself in a new industry (although often given as examples, Nokia's and IBM's transformations are exceptions). Although manufacturers typically have strong technology, product and manufacturing competencies and capabilities, they do not necessarily have close relations with their end users or competencies in the operation of their products. Sometimes the industry structure does not allow a manufacturer to gain access (distribution control) to its end users and the use of their products (Wise & Baumgartner 1999). Before a manufacturer can offer its products as services, it must be confident that it can gain access to their end users and able to establish a competitive service system.

A strategy is based on a company's overall mission, vision and goals. It is used to align a company's activities and organisation. Based on contingency theory, strategy consultants and scholars typically mention the following essential dimensions of organisations that should be consistent with strategy and among themselves (Peters & Waterman 1982; Andreasen et al. 1989; Cornet et al. 2001; Galbraith 2002; Neu & Brown 2005) (see Figure 2.42):

- **Structure** – the organisation of tasks, responsibilities and resources, decision making structure,
- **Processes and methods** – the processes and methods in the company
- **Capabilities and physical assets** – the technical resources and physical space
- **Measurement and rewards** – the manner in which performance is measure and people are motivated

- **People and competencies** – the knowledge and skills of the people in the company
- **Culture** – the norms, values and attitudes of the organisation

It is possible here to distinguish between hard and soft organisational dimensions, or to use engineering design terms: the characteristics and properties of an organisation. The first four dimensions are hard dimensions that can be 'designed' into an organisation, whereas the last two can only be influenced indirectly through management and the other dimensions. It should be noted here that strategy should not be seen as something is fixed and does not change, but is rather dynamically formed by the other dimensions with time.

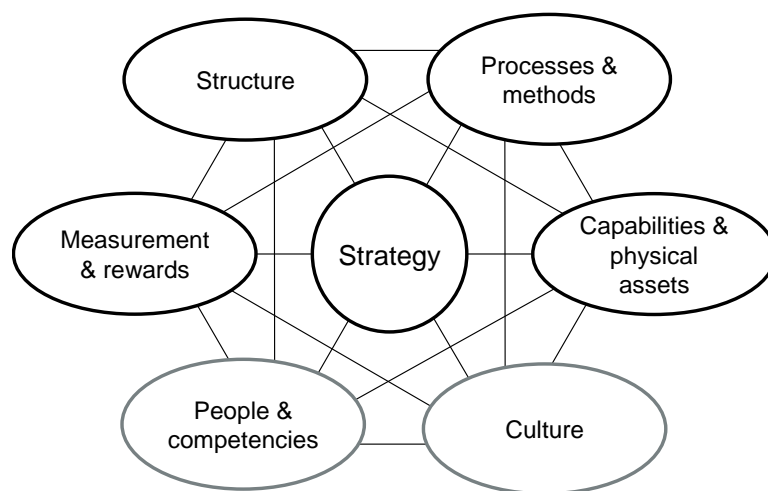


Figure 2.42 The essential dimensions of an organisation related to strategy (after Peters & Waterman 1982; Andreasen et al. 1989; Galbraith 2002). Culture, people and competencies are considered soft dimensions compared to the other organisational dimensions.

Porter's (1985) generic strategies are often cited as the reference for competitive business strategies. Porter defines three generic competitive strategies based on the how broadly the market is targeted and which core competencies of the company are applied:

- **Cost Leadership** – offering products and services at the lowest price on the market
- **Differentiation** – offering unique products and services that customers are willing to pay a premium for
- **Narrow focus** – focusing on a clearly defined market segment either by *cost focus* (offering the lowest price) or *differentiation focus* (offering unique benefits)

According to Porter, companies should stick to one these generic strategies and not risk being 'stuck in the middle' in order to be successful. Although widely adopted by many, this has since been challenged. In their book *Blue Ocean Strategy*, Kim and Mauborgne (2005) claim that the most successful firms are those that master both cost leadership and differentiation. Another classification of competitive

business strategies that has received attention in industry is provided by Treacy and Wiersema (1993):

1. ***Operational Excellence*** – providing the best total price of products and services in the most convenient manner for the customer (similar to cost leadership).
2. ***Customer Intimacy*** – delivering what customers want in a close, long term relationship (differentiation through customer focus)
3. ***Product Leadership*** – developing state-of-the-art products and services continuously (differentiation through product innovation).

Applying Porter's categorisation, PSS can be seen as a differentiation strategy (Tukker & Tischner 2006), as the provider complements the manufactured products functionality with a set of unique service offerings based on the provider competences. When compared to Treacy and Wiersema's strategies, PSS approaches seem to be a combination of best total price and close customer support. It would seem that PSS can be seen as a strategy for manufacturing firms to gain competitive advantage when differentiation on product properties alone on the market is difficult. Manufacturers must however be wary that their new service-oriented offerings might compete directly with (their own) product sales. In order to establish PSS on the market, manufacturers must demonstrate convincingly that the total cost of product ownership (or operation) is lower for customers with PSS compared to just product sales. The services offered could cannibalise product sales by keeping products operational for longer or using them more efficiently, so that the purchase of new products are postponed.

The type of service offered also influences the business strategy. In a large study of successful business units in European business-to-business manufacturing firms, Gebauer (2008) identified configurations of service strategies that correspond well to certain market conditions.

- ***After sales service*** providers seem to follow cost leadership strategies as the market here is typically highly competitive. Customers are price sensitive and expect service providers to react quickly to breakdowns and failures. After sales services are therefore often standardized, predefined and priced separately (unbundled).
- ***Customer support*** providers tend to differentiate themselves through their products and services. Customers of these services value high product quality and reliability backed with process-oriented services that prevent breakdowns altogether. Customer support services are bundled together in customised packages, i.e. Service Level Agreements, where customers pay a fixed price.
- ***Operational services*** combine cost leadership and the differentiation of their products and services. Customers that outsource expect that their initial investment, operational

expenses and risks can be reduced and managed more efficiently. Outsourcing partners have to assume full responsibility for their customer's operation processes, and therefore a clear legal agreement regarding division of responsibility and delivery scope is necessary. This means that operational services are standardised to ensure efficiency and typically high quality products are used to reduce breakdown and failures.

- **Research and development services** are often specific and differentiated offerings. Development partners collaborate closely with their customers, giving them a strong position on the market that creates strong barriers for competitors. As it is difficult for customers to assess the value of this type of services, the service provider uses their identity and reputation from their other products and services as a proxy for the value of their professional services. Given these conditions the competitive intensity is very low with these services.

As follows from the above, there are certain strategic characteristics that are common for all manufacturers that wish to offer services instead of selling products. The choice of strategy for a manufacturer to become service-oriented is dependent on many different organisational dimensions as well as the type of service offering it wishes to provide.

2.6.2 Structure and integration

According to Porter (1985) all companies may be seen as a chain of activities that add value to its offerings. These value activities can be divided into two broad types: primary activities and support activities (see Figure 2.43). The primary activities in a value chain are in and outbound logistics, operations, marketing & sales and service. Typical support activities are human resource management, technology (and product) development, procurement and firm infrastructure. These support the primary activities as well as the other support activities, but can also be associated with specific primary activities. Porter states that a *"firm's success depends not only on how well each department performs its work, but also on how well the various departmental activities are coordinated to conduct core business processes."* The model shows that value activities are not necessarily the same as functional units in an organisational structure, e.g. Engineering Design, Quality Assurance, Service Technician staff, etc. Development activities are therefore not just limited to the R&D or product development department, but can happen anywhere in the whole value chain (Andreasen et al. 1989). In fact the manner in which the value activities are connected, is what actually leads to competitive advantage.

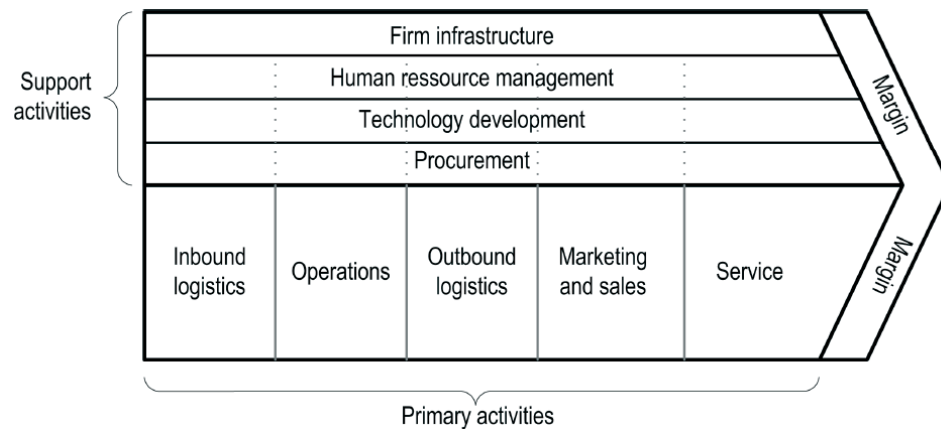


Figure 2.43 Porter's (1985) generic value chain model.

In smaller companies the integration of activities happens naturally, whereas in larger organisations this is a more challenging task. Ölundh & Ritzén (2003) observed that in smaller companies products and services are developed more closely but ad hoc, whilst in larger companies products and services are separated and the product development process is more structured. Although interrelations between a company's activities can provide benefits for the whole value chain, one has to consider that the costs of creating, maintaining and developing these interrelations, do not always outweigh the benefits.

A dichotomy exists in all manufacturing organisations between the exploitation of available knowledge (internal integration) and the exploration of new possibilities (external integration) (Lenox & Ehrenfeld 1997). In some cases it is more advantageous to allow certain parts of an organisation develop products (or services) on their own as existing organisational structure and strategy can restrict radical innovation (Bower & Christensen 1995). Companies should balance when it is more beneficial for organisations to keep activities (e.g. development of products and services) separated or integrated.

The value of PSS approaches will only be realised if synergy or integration benefits can be achieved. Three dimensions of integration can be identified:

- **Strategic integration** that binds decision-making and company activities to a focused direction that allows an organisation to distinguish itself in the marketplace.
- **Functional integration** which organises and links the various functional areas of a company to work together more effectively and optimise the whole.
- **Logistic or supply chain integration** which extends integration concepts beyond the company's organisation to its customers and its suppliers.

PSS approaches are integrative strategies and therefore it is essential to understand how development activities in manufacturing firms should be organised and coordinated with the other value activities in the internal organisation (vertically and horizontally) and the external actor network.

2.6.3 Product development strategies

The research literature on business strategy has been mainly based on manufacturing firms. Here a large emphasis is on the role of technology and product development in a company's strategy. Product development typically has a high priority in manufacturing firms as it defines its business success in the future. Manufacturing firms tend to structure their development activities in *strategic business units* according to technologies and products. These have their own objectives to generate business and ensure that their range of products are constantly updated and renewed. Strategic business units are accountable to the company in making sure the right products are developed on time and as efficiently as possible.

Product planning and *portfolio management* are processes in strategic business units that aim to effectively transform business strategy into actual products and services (Malinen 2000). Product planning is an ongoing process in manufacturing companies, where development projects are regularly evaluated, selected and prioritised (Larsson 2007). During this process resources are allocated and redistributed.

Product development consists of different tasks or types of projects that link a company's business strategy, product strategy and technology strategy to the market and customers (see Figure 2.44). Five general types of projects may be identified in product development (Andreasen et al. 1989):

1. ***Business oriented projects*** – new product development, product variants, product, product updating, etc.
2. ***Research oriented projects*** – technology research, technology development, business research, etc.
3. ***Cross-disciplinary projects*** – platform architecture, system design, integration of systems, etc.
4. ***Support projects*** – supporting tasks for all the other functional units, e.g. technical product information, drawings, etc.
5. ***Renewal projects*** – generic projects, development of design methods and processes, etc.

Business oriented projects benefit from exploitation of existing knowledge and resources, whereas research oriented projects benefit from exploration of new knowledge and collaboration with external resources. These individual projects in product development are temporary endeavours with a clear objective, schedule and budget.

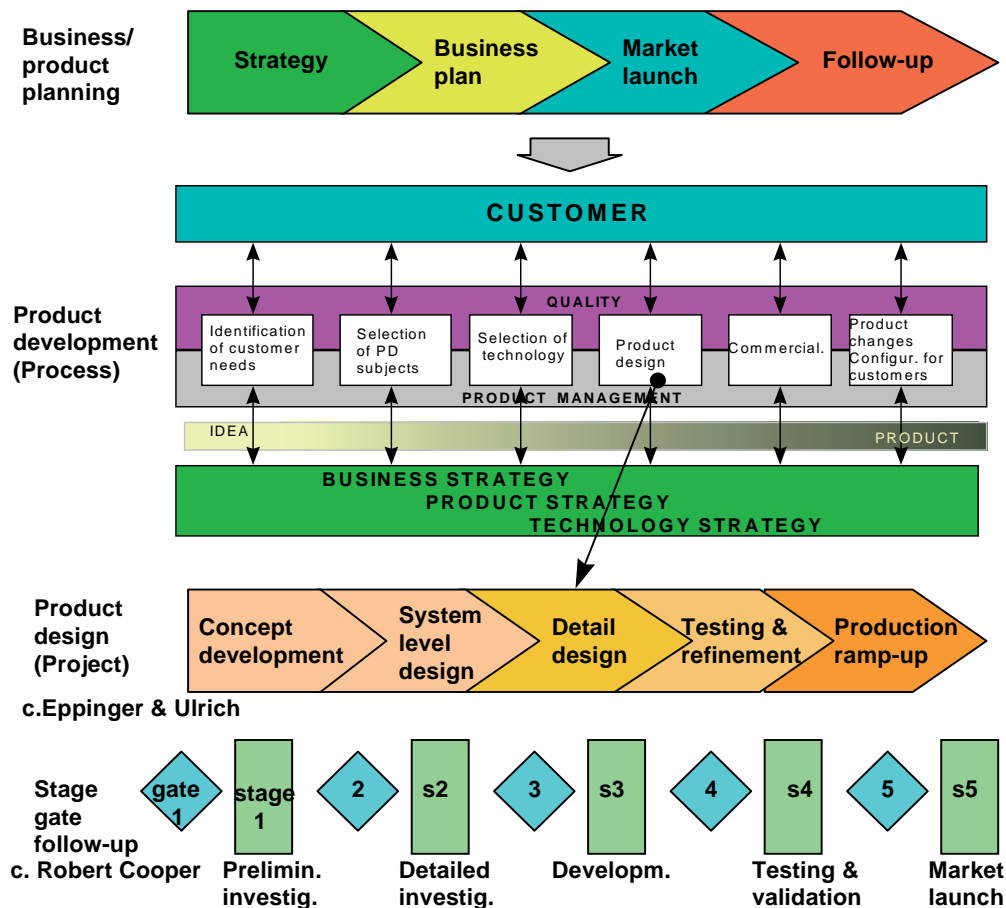


Figure 2.44 A general model of different processes related to product development from the Finnish research agency TEKES (Malinen 2000). Product development links the business strategy to the customer.

PSS development in this respect is therefore not just a single individual development project in a company, but is related to product planning and overall business strategy. With PSS approaches manufacturing firms have to plan, initiate and manage several types of projects that together lead to PSS.

2.6.4 Service development strategies

Manufacturing firms tend to view their service operations as necessary to support the core product business, but they are often separated from the product-oriented activities and by no means equal in strategic or operational importance (Goffin 1998; Glueck et al. 2006). This could partly be due to that services tend to be more easily copied compared to products and therefore might not lead to lasting competitive advantage. The strategic implications of services have not enjoyed as much focus as products in industry or among researchers, and therefore the development of services is typically not approached as systematically. As strategies dictate how organisations should make the appropriate organisational arrangements and resource allocations, firms that wish to be service-oriented should also have a clear service strategy in place (Gebauer et al. 2005).

Compared to products, service strategies are generally based on customer orientation and the long-term perspectives of customer relations. Interestingly enough, whilst manufacturers have been moving to more service-orientation, companies in the service industries have been adopting product-oriented strategies in their development of services (Bowen et al. 1989; Bitran & Pedrosa 1998; Nallicheri & Bailey 2004; Hollins 2006). Here services are standardised, automatised, and quality controlled to increase productivity.

Service-oriented organisations are typically organised in teams that deal with certain accounts or customer segments, rather than technology or product categories. Service development in such organisations is typically ad hoc and part of customer relationship development, e.g. Ölundh and Ritzén (2003) observed that services in manufacturing firms tend to be developed locally and customised in the sales process. Some manufacturers have however centralised their service development activities to increase knowledge sharing and achieve integration and productivity benefits. Service development is however still encouraged locally, as sales units have intimate knowledge of the customers and need to be flexible when providing customised solutions.

Cavaliere et al. (2007) identified four strategic profiles for service depending on their importance to the manufacturer:

- **Product support**, services are a cost centre and 'necessary evil'
- **Cash generator**, services represent a good source of revenue by selling spare parts and accessories
- **Business generator**, services are a business leverage for the company and gains access to markets and customers
- **Brand fostering**, services are essential to the companies current and future business

The above profiles correspond to Goffin's (2000) description of the stages manufacturing firms go through as they recognise the importance of service support (Figure 2.32). Related to the above listed strategic profiles, Gebauer (2008) explored configurations of service strategies in manufacturing firms by exploring their market conditions. He discovered that:

- **after-sale services** tend to follow *cost leadership* strategies as these services are fairly standardised and the market environment very competitive;
- **customer support services** tend to apply strong *differentiation strategies*, where companies customise their products and service offerings to individual customer needs;
- **operational services** (i.e. where a customer activity is outsourced) combine *cost leadership and differentiation strategies* to provide customers a service or specific performance at lower costs than they would be able to achieve themselves; and,

- *research and development services* (e.g. corporate consultancy services) are highly specialised and customised knowledge intensive services, which are unique and hard to imitate, and therefore companies typically apply *differentiation strategies*.

Although the literature on service design mainly focuses on services from the service industry, there has been some research of service development in manufacturing firms particularly in after-sales services.

After-sales service strategies

Strategies for after-sales services tend to be based on cost, response time and reliability. Lele (1997) describes how after-sales service strategies can be appropriately linked to the type of product being serviced. Product design and service support strategies should take into consideration the fixed and variable costs that customers bear in the event of product failure. The extent of these costs determines what kind of strategy would be most effective (see Table 2.2).

Segment	Key customer concerns	Product strategy	Support strategy	Keys for success	Examples
Disposable Low fixed costs Low variable costs	High reliability Low replacement costs Repairability not important	Very high reliability Low manufacturing costs	1-2 year warranty	Very high reliability Low product costs Credibility, reliability, warranty	Swatch
Repairable High fixed costs Low variable costs	High reliability Moderate/low expected repair costs Low skill requirements/ easy available service	High design reliability Repairability important in design	Conventional, i.e. on site Wide availability, e.g. do-it-yourself kits, third party service, etc.	High reliability Design simplicity Low repair costs	Maytag Sears/ Whirlpool
Rapid response Low fixed costs High variable costs	Downtime/failure Operational availability Service support costs	Balance: - Reliability - Ease of repair Standardise parts to lower logistic costs	Mix: - Loaners - On-site maintenance Maintain high fill rates in logistic system	Ability to choose most cost-effective mixture of design and support	Caterpillar Deere
Never fail High fixed costs High variable costs	Protection against any and all failures and interruptions Affordability	"Fault-tolerant" design Built-in or add-in redundancy Deliver to acceptable cost	Back-up maintenance Inspection/ replacement	Very high component reliability Cost-effective design Credibility	Tandem

Table 2.2 The characteristics of customer costs point to what would be the most effective product design and service support strategy (Lele 1997).

The customers' needs and willingness to pay determines the type of business model that are most relevant when offering after-sales services (Cohen et al. 2006). Very reliable products that are easily replaced and do not involve high costs do not demand much after-sales support, whereas products that always need to be in operation and involve high costs to the customer in case of failure are more pertinent to service-oriented business models (Table 2.3).

Service priority	Business model	Terms	Example	Product owner
None	Disposal	Dispose of products when they fail or need to be upgraded	Razor blades	Consumer
Low	Ad hoc	Pay for support as needed	TVs	Consumer
Medium-high	Warranty	Pay fixed price as needed	PCs	Consumer
Medium-high	Lease	Pay fixed price for a fixed time, option to buy product	Vehicles	Manufacturer, leasing company
High	Cost-plus	Pay fixed price based on cost and pre-negotiated margin	Construction	Customer
Very high	Performance based	Pay based on product's performance	Aircraft	Customer
Very high	Power by the hour	Pay for services used	Aircraft engines	Manufacturer, service provider

Table 2.3 The prioritisation of after-sales services determine what kind of business model could be best suited to use in a manufacturing company (Cohen et al. 2006).

A major challenge for service operations is to balance the assets and resources available and the fulfilment of unpredictable and sporadic demand (Cohen et al. 2006). As services are locally delivered, these are typically linked to distribution channels (Goffin 1999; Saccani et al. 2007). Even with services delivered directly from a manufacturer to customers, it is difficult to establish a link between product development and service operations. When manufacturers choose to use external partners to provide services for their products, it becomes even more challenging to ensure that use information about the products and customers is fed back to the manufacturer.

Some researchers have studied the antecedents for successful service design. Involving customers in the service design process does also seem to lead to more innovative services (Matthing et al. 2004), but interestingly several researchers have observed that the integration of service employees in the development process did not play such a forceful role to the success of services as would be anticipated (de Brentani 1991; Kelly & Storey 2000; Antioco et al. 2008; Gebauer et al. 2008). Likewise top management commitment and strategy does not necessarily have a significant effect on the success of new services (Kelly & Storey 2000; Antioco et al. 2008). The researchers do however reflect that the sharing of information across the organisation and multidisciplinary teams is still important and the reason to this observation is that this might be due to new service development typically being an informal process (Kelly & Storey 2000).

The move from traditional service delivery in manufacturing firms to the delivery of performance and optimisation of the customer's activities, demands more than just development of new services. This requires an integrated approach of business model, product and service development and operations. This is what the next section will attempt to shed a light on.

2.6.5 PSS development strategies

Product-oriented business strategies are dependent on the maturity of the product technology and its adoption in the market, but this does not necessarily determine how apt it is to PSS approaches. Successful PSS can be found in both the case of the introduction of new technology (e.g. the use of electrophotography in Xerox's Model 914 (Chesbrough & Rosenbloom 2002)) and the case of mature products (e.g. SKF ball bearings (Reinartz & Ulaga 2008)). The premise of PSS' economic and environmental benefits arises from matching the potential utility of products throughout their life with the value achieved in customer activities. The full potential of PSS can only be achieved when the integration of products and services are considered strategically.

McAloone (2005) asserts that *"service-oriented product development requires vertical integration within the organisation, due to the fact that the PSS regards both core business decisions, product planning, product life cycle management and detailed product development expertise."* PSS development needs to be considered on four levels:

1. At an **organisational level**, it relates to business ventures and the creation of new business models based on core competencies in the organisation or opportunities arising from collaboration with external partners and the formation of new actor networks.
2. At a **business level**, it represents a different approach to business, moving from traditional product manufacturing and sales to service provision and customer relationships. Here companies need to understand how they can capitalise on the internal and external opportunities of service-orientation.
3. At a **system level** where multiple systems (e.g. product system, supply chains, product life cycle systems, customers' systems, etc.) are linked together through PSS to form new interdependent relationships that are not present with traditional product sales.
4. At a **product level**, PSS approaches prompt a better understanding of product lives; the interdependent relations between products and services; and models for PSS conceptualisation.

Above mentioned levels are of course also important to consider (see sections 2.5.1 and 2.6.3) in traditional new product development, but in the case of new products many business structures and processes are already given in the company. With PSS development many of these product-oriented business practices need to be re-thought to suit service-oriented approaches.

The manufacturer's product itself can indicate how suited service-oriented offerings would be on the market. Capital equipment is often

mentioned as befitting for PSS (Windahl 2007), but in general PSS approaches seem to work well for product manufacturers if any of the following conditions apply (Tukker & Tischner 2006):

- products with high costs to operate and/or maintain;
- complex products that require special competences to design, operate, manage and/or maintain;
- products with considerable consequences or costs if not used correctly or appropriately;
- products where operational failure or downtime is not tolerated;
- products with long life; or
- products with only a few major customers on the market.

For PSS in the context of manufacturing firms the underlying assumption is that they can capitalise on their substantial experience and expertise of their products, and thus create service offers that would not be feasible for other players on the market (Mathieu 2001b). Given these strengths manufacturing firms should start by considering their existing market and customers to determine where PSS approaches might hold strategic opportunities to leverage their competitive position.

Transition from product-orientation to service-orientation

There are many paths to becoming a service-oriented manufacturer. Some companies build upon a consolidation of their product-related services and then enter the installed base market (Oliva & Kallenberg 2003). Others make the migration by building up competences in e.g. systems integration, operational services, business consultancy and financial services to deliver integrated solutions (Davies et al. 2006). Most often however, companies are not that well coordinated and simply attempt to adhere to customer's requests provisionally. No matter what the chosen path will be, a coordinated approach guided by the strategic commitment of the company is necessary to yield the largest benefits from the migration.

Based on 11 capital equipment manufacturers Oliva and Kallenberg (2003) proposed a process for the transition from product manufacturer to service provider (Figure 2.45). The stages that manufacturers may take are:

1. ***Consolidating product-related services.*** Establishing a service dedicated organisation that is responsible for all service offerings. This is done to improve the efficiency, quality and delivery time of the provided services, as well as monitor current service operations to inform whether the company should move further into services. Additional services to supplement the existing set are also developed.
2. ***Entering the installed base service market.*** If business opportunities are identified in providing services to the installed

base (i.e. products that are currently in use), a separate service organisation is set up with its own sales force and profit centre. The two major challenges identified here are the change in culture between product and service orientation, and the creation of a global service network and infrastructure that can respond to local requirements. Companies use this stage to establish themselves on the service market.

3. **Expanding services.** Two transformations happen in this stage:
 - a. **Expanding to relationship-based services.** This represents the move from business based on transaction (of labour and materials) to performance. Here the service provider assumes the risk of equipment failure, but at the same time this reduces the variability and unpredictability of demand and increases utilisation of the service system.
 - b. **Expanding to process-centred services.** Here the focus moves from the performance of the product to the performance of the customer's activities. Services are offered that support and continuously improve the utility of the product in relation to the customer's objectives. New competencies and capabilities need to be developed here to suit these types of services.
4. **Taking over the end-user's operation.** This stage is where the company takes responsibility of the customer's processes and becomes a strategic partner in development and operation in their business.

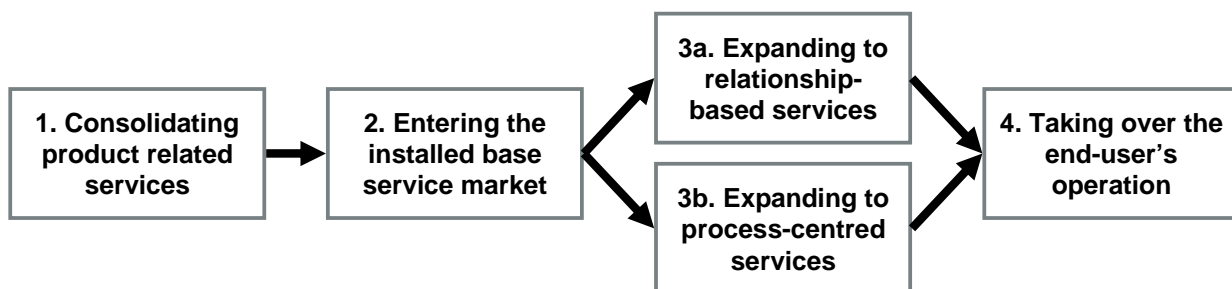


Figure 2.45 Oliva and Kallenberg's (2003) process model showing the different stages of transition a manufacturer goes through to become a service provider.

Even though the phase of taking over the end-user's operation is outlined, the researchers did not observe this move amongst any of the 11 equipment manufacturers. Oliva and Kallenberg do however remark in their observations that the early separation of product and service operations can limit the benefits of product and service integration.

Reinhartz and Ulaga (2008) proposed a similar approach for product companies wanting to offer services profitably. Here they point out that the service sales process is often more complex and strategic, requiring decisions made high up in the customer's organisation. In their studies

Reinhartz and Ulaga do not conclude that separating the service sales organisation is always the best configuration, but the sales force does need to be “*service-savvy*”. This is backed up by observations made by (Johnstone et al. 2008) and (Galbraith 2002) that state that different configurations of organisational structures can lead to successful service orientation.

Although the move towards integrated solutions is portrayed here as linear and straightforward, this is not the case in reality (Windahl 2007). An important aspect the researchers also point out is that integrated solution providers need to think about how to gain access to the customer through channels that are already controlled by other companies (Foote et al. 2001; Davies et al. 2006). Furthermore, the increased dependency on customers and external partners need to be effectively managed when developing and commercialising integrated solutions. This is an on-going and ever-changing process that is difficult to define beforehand.

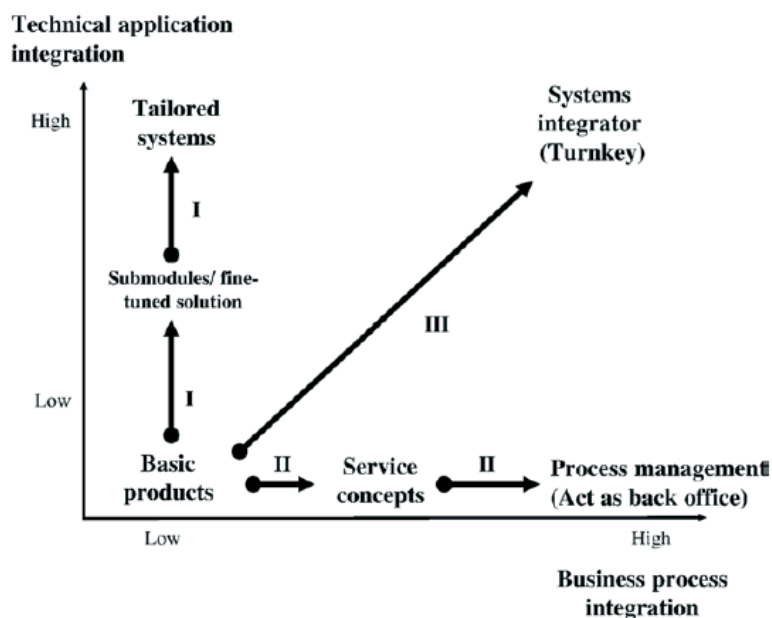


Figure 2.46 Matthyssen and Vandenbempt (2008) identified three strategies for manufacturing firms to become service-oriented.

The above described process is merely a rationalised model of the process. Manufacturers will experience the transition process from products to services to be more dynamic and complex with many barriers and challenges along the way. Instead of a radical organisational change to a total systems integrator, where the competence gap may be too high Matthyssen and Vandenbempt (2008) suggest incremental moves along either (see Figure 2.46):

- **Technical application integration**, where products are developed and integrated to become customised systems. This strategy is preferred by companies that operate far upstream from the end users.

- *Business process integration*, where products are provided as services and process management. This strategy is preferred by companies that operate close to the end users.

Corporate consulting is an example of a fairly simple first step to offering services with products (Sandberg & Werr 2003). Based on the traditional business' products or expertise, a manufacturer can effectively establish a team of high level customer-oriented consultants. These consultants can then leverage the close relations with the customer to develop new products, services and business opportunities. This strategy is applicable to business-to-business companies to generate synergy effects with their product business and learn about and from their customers. Although still challenging, these more incremental steps are simpler to implement in manufacturing firms, involve less risk and allow the traditional product-oriented business to go on with "business as usual."

In the innovation management literature there is an on-going discussion to whether it is best for established firms to create separate organisations to develop, sell and provide radically new business offerings or whether it is possible to build new capabilities within the current organisation's structure (Bower & Christensen 1995; Chesbrough & Rosenbloom 2002; Bullinger et al. 2003). New venture divisions enable companies to quickly build new capabilities, but tend to also limit their ability to leverage existing capabilities (Berggren & Nacher 2001). This discussion is also relevant when it comes to PSS. With PSS approaches, should a manufacturer establish independent service-oriented business units, or integrate service-orientation into all business units?

In order to obtain service-oriented capabilities manufacturers may choose to

1. develop these competencies and capabilities in-house,
 - a. either by changing the entire current organisation
 - b. or developing a separate organisation within itself;
2. acquire an organisation with the necessary competencies and capabilities; or
3. partner with an external organisation with the necessary competencies and capabilities.

The choice amongst the above options is based on the organisational structure and degree of integration between the business units as discussed in section 2.6.2. The last two options would seem to be the quickest way to establish service-oriented capabilities, but face the challenges of integration.

	Level 1 Grow the front end	Level 2 Build the back end	Level 3 Refocus
Learning processes	Explore new approaches and structures for integrated solutions delivery Learn from vanguard projects and use tacit knowledge gained in subsequent projects Systematically capture and transfer learning from project to project	Explore new approaches and structures that support front-end units Develop and implement strategy to replicate solutions-ready components Learn from front-end experiences and codify knowledge gained	Exploit corporate-wide learning and leverage knowledge assets Strategic centre manages front-back and internal-external flows of knowledge
Capability building	Front-end capability embodied in vanguard projects Move from customised to standardised offerings (e.g. standardised service portfolios for reuse in subsequent projects)	Develop menu of standardised solutions-ready components to support the front end Create and refine product platform and services portfolio	Create and refine corporate-wide capabilities – front, back and centre – which support large-scale and repeatable solutions delivery Balance front-end pull of customisation and back-end push standardisation
Organisational change	Embed response to new solutions opportunity in: - Existing business unit - Separate pilot organisation Work with lead customers Use partners to fill gaps in capabilities	Create stand-alone back-end product and/or business units Strategic partnerships with major customers Strategic partnerships with product and/or service component suppliers	Focus activities of company or business unit on integrated solutions provision Move out of peripheral businesses Establish structures (front, back and centre) that support repeatable solutions delivery Prevent back-end units from having direct contacts with customers

Table 2.4 To become an integrated solutions provider companies must move through three levels of organisational capability (Davies et al. 2006).

Some researchers (Oliva & Kallenberg 2003; Gebauer et al. 2005; Mills et al. 2008) believe that it is necessary to separate the service organisation as an independent profit centre, so that it can act as a shelter for the development and support of a service culture. In this way the business unit can create an explicit service strategy, business model and identity. Others (Tidd et al. 2005; Davies et al. 2006; Matthyssens & Vandenbempt 2008) think that this will omit the competitive advantages that manufacturers have by integrating products and services suggest establishing '*front-end customer-facing units*,' '*back-end capability providers*' and '*strong strategic centres*' to mediate between the business units (see Figure 2.47). The idea is to establish a separate unit with strong strategic links so that the service-oriented unit can have the entrepreneurial benefits of a small organisation whilst being able to access the resources of a large organisation.

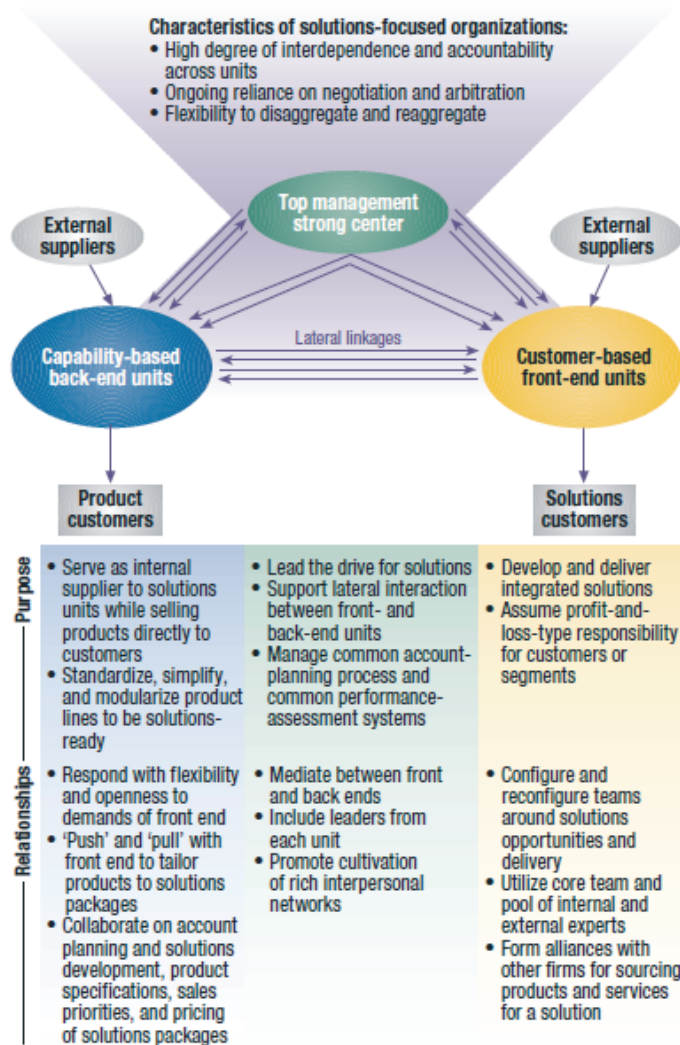


Figure 2.47 Foote et al. (2001) identified that successful solution providers reorganised themselves to form 'front-end customer-facing units', 'back-end capability providers' and 'strong strategic centres'.

The service-oriented business units develop integrated product and service solutions for customers whilst the traditional product-oriented units continue with "business as usual." The degree of integration between the business units in a service-oriented organisation depends on four dimensions (Galbraith 2002):

- **Type of solution** – vertical (industry and customer specific) solutions require a more customer-centric organisational unit than do the horizontal (broad application) solutions,
- **Scale** (number of products and services offered) and scope (number of different kinds of products and services that are combined in the solution) – the larger the scale and scope the larger the number of organisational units that must be coordinated,
- **Integration of the solution** – the more interdependent the components, the more interdependent the organisational units responsible for those components need to be.

- *Revenue from solutions* – the percentage of total revenues that comes from solutions, higher percentages justify stronger customer-oriented business units.

The higher the potential is for synergy effects, the greater the need for tight links between business units (Sandberg & Werr 2003). In order to fully benefit from the advantages of PSS approaches the firm's business strategy must be broken down into clear objectives for each of the functional units in the organisation. These objectives determine the task, structure and strategy of each unit and how they mutually support each other.

2.6.6 Summing up - strategic management

With PSS approaches a dependency is created between a (providing) company's operations and a (receiving) customer's activities. As a result the integration of operations has to be carefully managed, both tactically and strategically. PSS development models should therefore elucidate integration across the different levels of the company's development activities:

- *Strategic business/product planning* in cooperation with networks and service partners, i.e. development of PSS concepts.
- *Product management and product development projects* leading to new PSS 'offers', i.e. development of the product/service offer.
- *PSS delivery system or function*, which in steady relation to the customer delivers services, i.e. offer customisation and development of the service channel.

Literature on the strategic aspects of PSS development provide some insight on appropriate matches between type of products, customer needs and willingness to pay, product development strategies, service support strategies and business models. Strategies in PSS development must take into account how all these individual elements can be brought together to form a strategy that capitalises on the integration of products and services.

Several researchers have proposed transition process models outlining the main steps for a manufacturer to become more service-oriented. These however seem to provide a very simplified view of a major strategic shift in a company. They do not seem take into consideration that the transition to PSS approaches is a result of interaction and collaboration with internal and external actors (e.g. different functional units, customers, suppliers, etc.), and not just a process where the manufacturer is the only driving force.

The implications of PSS approaches on the organisational structure depend on how integration can be effectively ensured between the different functional units (e.g. back-end product development, front-end

service providers, etc.). It is generally agreed that the integration of activities across the organisation is key to providing successful PSS, but it is not clear how the development activities on the different levels of the organisation should be coordinated with customers and external partners.

2.7 Summary

In this chapter the literature related to PSS development was reviewed. Three different perspectives were used to structure the literature:

- From a *design object perspective*, products, services and PSS are all seen as value propositions that aim to fulfil a need with their customers. In essence products and services are just different alternatives to how companies deliver value to their customers. The 'product' versus 'service' discussion is not so much an issue of a new 'object' that has to be developed, but a new perspective on what kind of value is being created and is an opportunity to expand designers' mental space when designing by considering e.g. customer activities, service content and service channel, actor networks, new business models, etc.
- From a *design process perspective*, the generic design stages and activities common in product development are also present in service and PSS design process models. Service-oriented development models are however more customer-oriented and often involve the customers in both the design and operation phases. As PSS development represents a broader scope of new design dimensions, it remains important for designers to understand the relation between decisions made in the design process and the affect they will have in the ensuing product life phases and customer activities.
- From a *strategic management perspective*, PSS approaches can be seen as a new strategic business opportunity based on the ability to integrate activities and competencies across the organisation and link them to customers and others in the actor network. This entails both vertical integration, from strategic to operational level, and horizontal integration, across internal functional units to customers and other external actors. The shift from product-orientation to service-orientation is a complex and dynamic process, and in order for manufacturers to take full potential of PSS approaches they must understand how organisation factors (e.g. competencies, structure, culture, processes, etc.) can be brought together to form a strategy that capitalises on integrating products and services.

The reviewed literature shows that the concept of PSS development is multifaceted and it is not clear how it can be understood as an operational design approach. The literature does however reveal theories and ideas to how manufacturing firms can take advantage of

adopting PSS approaches. The above insights from existing literature will form the basis for analysing the case studies in this thesis (Chapter 4), and building a theoretical foundation for the synthesis of PSS (Chapter 5).

3 Research methodology

The research in this PhD project belongs to the academic field of *Design Research*. The purpose of Design Research is two-fold: to advance the understanding of the phenomenon of design through the formulation and validation of models and theories; and, to develop the practice of design by improving the design process through knowledge, methods and tools (Blessing 2002). The objectives of the research in this thesis, as stated in Chapter 1, reflect both these aspects of Design Research. First of all the research sets out to establish a theoretical foundation for PSS design, and then it should propose service-oriented development strategies and methods for manufacturing firms. But before this is done, in order to ensure the results of this thesis are convincing, the manner in which the research is conducted will be explained.

Design as a phenomenon is a complex and dynamic activity that involves artefacts, people, organisations, tools and methods as well as the socio-economic context it takes place in (Wallace 1997). There are many perspectives that can be taken when studying such a phenomenon and each perspective might result in different perceptions or understandings. It is therefore important to make it clear what is the researcher's world view, how the researcher acquires knowledge about the research phenomenon, and what are the sources of information used in the research. Hence this chapter aims to clarify how the research in this PhD project has been conducted, and which approach and methods were applied to answer the research questions posed in Chapter 1.

3.1 Research paradigm

This research operates mainly within the theoretical framework of two specific areas of Design Research, *Engineering Design* and *Product Development*. In the field of Engineering Design the understanding of synthesis of technical systems is central (as opposed to other engineering disciplines that focus on analysis). Although related, Product Development research focuses more on the organisation and coordination of development activities in organisations.

Engineering Design has its roots in *systems thinking* and the principle that one can breakdown a problem to smaller problems, solve these and then be able to put them together again and thus have solved the whole problem (Blanchard & Fabrycky 1998). Product Development evolved from a framework of *Scientific Management* and now attempts to understand the field from a perspective of bounded rationality (Cooper 1992). Both areas of Design Research belong to a 'logical engineering' approach (Stoltermann 1994) that assumes that design processes and methods on the whole are independent of the individual designer or

design team, and can be communicated to others and re-enacted effectively (see Table 1.5).

Although the research in this thesis is very rooted within a logical engineering paradigm, perspectives from social theory, in particular *Science and Technology Studies (STS)* are considered. This complements the dominant understanding of design processes, and emphasises the social issues by providing explanations of e.g. how management approaches (Latour 1991) can be understood in organisations, or how users and their use activities can be seen as designers and part of the design process (Ingold 2006). Furthermore social theory can be used to better understand the ever present political processes in organisations and the social context development activities operate within.

	Logical	Psychological
Design process	Prescribed guidelines	Own personality, ideals and values
Rationale	Possible to deduce a rational	Acts on a concealed rational
Designer's role	As independent of the designer as possible	Able to recognise and possess own style and preference
Design solutions	Directed by the design process, possible to direct solutions	Knowledge and ideas lead to good design solutions
Design education	Evaluation of project documentation and the decisions made	Discuss the student's design solution, little attention is paid to the process

Table 1.5 Two opposing schools of thought in Design Research (Stoltermann 1994).

Research in Engineering Design and Product Development aims to improve design, i.e. the process and ultimately the products of design (Blessing 2002). The scientific paradigm is however bounded by scientific management principles that are logical, deterministic and largely based on cause and effect principles, which influences how a researcher understands a phenomenon. Although it is not possible to reach an objective understanding of reality it is the author's ambition to provide as rich an understanding of PSS development activities as possible.

3.1.1 Epistemology

Due to the differences in design approaches, it is necessary to establish the conditions of the theories on which the knowledge in this thesis is based. In Design Research three types of knowledge are created (see Figure 3.1):

- *empirical findings*, which are based on the study of design in practice;
- *contributions to design theory*, that explain the phenomenon of design; and,
- *contributions to work practice*, that enlighten and improve the design process in practice.

The different types of knowledge of design influence each other and all contribute to the understanding of the phenomenon of design. The research in this thesis builds upon what is currently known about PSS design from theories, and existing descriptive and prescriptive knowledge, and then uses empirical observations of PSS design to compare and challenge what is currently known. The aim of doing this is then to improve the integrated development of products and services in practice.

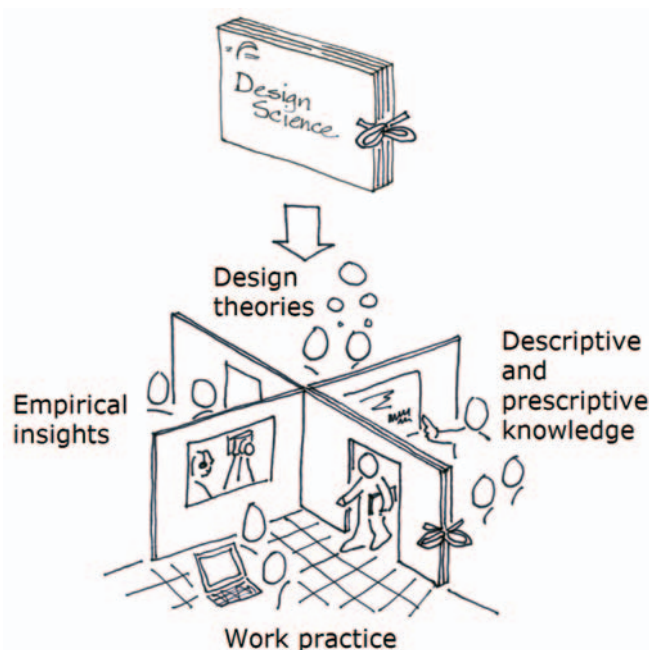


Figure 3.1 Design Science (also known as Design Research) can be seen as design theories based on empirical insights from work practice to formulate descriptive and prescriptive knowledge (Andreasen 2008).

In scientific research there are different approaches to apprehending the relationship between empirical data and theory. *Epistemology* is the study of knowledge and its origin, nature and limitations, or simply put, how do we acquire knowledge? There are three general ways in which we understand the world around us, see Table 1.6.

Positivism	Interpretativism	Social constructionism
<ul style="list-style-type: none"> - Assumes that an objective reality and truth exists. - Knowledge is independent of the observer. 	<ul style="list-style-type: none"> - Assumes that access to reality is through the interpretation of language, consciousness and shared meanings. - Aimed at understanding the context of the subject, and the process whereby the subject influences and is influenced by the context. 	<ul style="list-style-type: none"> - Assumes that social reality is historically constituted and that it is produced and reproduced by people. - Knowledge is dependent on the individual.
<i>"The whole is equal to the sum of the parts"</i>	<i>"The whole is different from the sum of the parts"</i>	<i>"The whole exists only as a socially constructed structure"</i>

Table 1.6 Three general categories of research epistemology (Orlikowski et al. 1991).

Although the research paradigm is within engineering, the social aspects of design are acknowledged. It would not be suitable to assume a purely positivistic engineering approach in this project. This project deals with design and development activities, which at its core is about people working together. The epistemologic approach to this research would have to take into consideration that multiple human and social perspectives exist to what is going on and why. However, the research in this thesis does not subscribe to social constructivism as the process of design is not perceived to be solely dependent on the individuals, but involves technical knowledge that is independent of the individual.

As the nature of Design Research is both to understand design and to improve it, the practice and the theories and models to describe them are constantly evolving and changing with social, technological and economic advances. Here *critical rationalism* as a scientific approach is well suited to Design Research (Popper 1963). Critical rationalism assumes that an objective truth exists, but it can never be justified. Theories can therefore not be proven, but they can be falsified. The field of Design Research advances by constantly challenging the current models and theories and disregarding those that do not support new insights. In this respect this PhD project can be seen as an attempt to challenge Engineering Design and Product Development methodologies with service-oriented offerings. The approaches described in Table 1.6 should not be seen as exclusive of each other when performing research, but in this project an interpretative research approach seems to be the most appropriate, as it acknowledges how individuals and actors are capable of influencing the whole system.

The researcher's pre-knowledge and perspective

The 'instrument' for gathering data in this project is the researcher himself, and is therefore both informed and biased by his own background and knowledge within the area. The author has a M.Sc. in Mechanical Engineering and has worked as a mechanical design engineer for 4 years. He has worked as a consultant and been skilful in the use of many methods in Engineering Design in many different companies and projects. His personal experiences have been useful in understanding the usefulness of design methods in real life as well as how to communicate and interact with companies. Here he has observed how individuals, social systems and political processes are a big part of design processes. This has allowed him to attune of the real world context of design and development activities. However this experience and insights do create a bias and the researcher has often questioned himself if Abraham Kaplan's "*law of the instrument*" comes to play; "*if all you have is a hammer, everything looks like a nail.*" With a strong background in Engineering Design, the researcher risks being biased towards traditional design methods as being the answer to PSS design. However as will be discussed later in section 3.5, the researcher has

attempted to be reflective on this bias and discussed the observations with other informants to provide other perspectives.

3.2 Research object and objective

The research object, objective and questions were established in Chapter 1. The research object in this thesis is *“the design and development activities in manufacturing companies that lead to PSS approaches.”* The research objective is *to establish a theoretical foundation for the systematic and methodological approach to PSS design; and, to propose service-oriented development strategies, methods and techniques for manufacturing firms that wish to adopt PSS approaches.* In line with Design Research, this project aims to investigate how PSS design is done in practice in order to contribute to its understanding and to improve the design process to achieve the sustainability potential of PSS. This influences the appropriate choices of the research methodology for this PhD project. As design is a socially-mediated, technical activity (Shah et al. 2004) and what is of interest in this research is the activities in the ‘real world’ context of manufacturing companies, this places the research in the field of social science. At the same time the research aims, not just to be an academic exercise, but to be applied and made relevant for practice. So two scientific paradigms come to play in this research (see Figure 3.2).

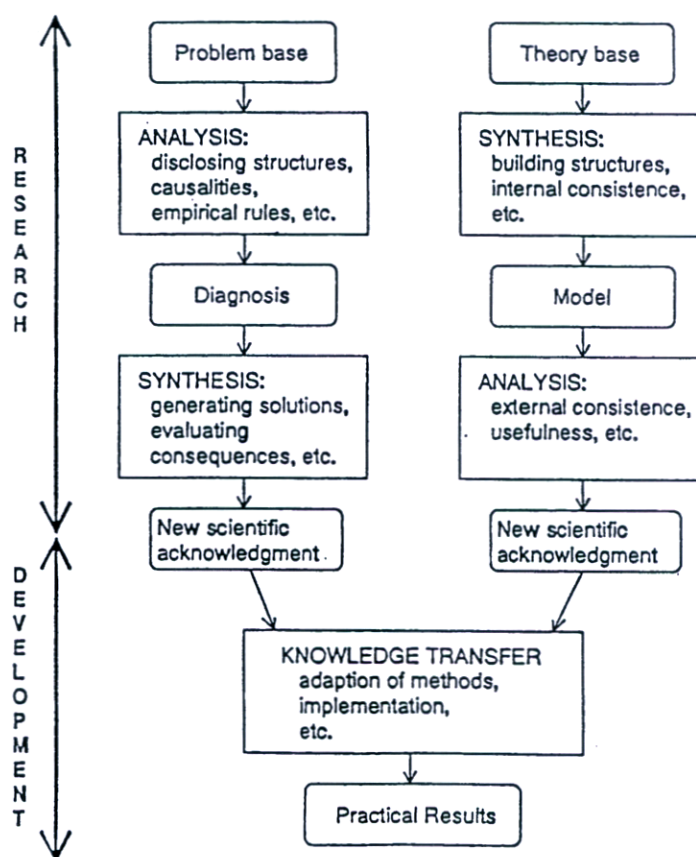


Figure 3.2 A model for applied research which either addresses a base of conceived problems or a base of existing theories. This shows how theory and empirical insights both lead to new knowledge (after Jørgensen 1992).

On one hand the research is *problem-based*, there is a need for more service-oriented and sustainable approaches to our industrial systems and manufacturers today are struggling to achieve this. On the other, the research is *theory-based*, Engineering Design has focused on physical and technical artefacts, but does not explain the design of services very well.

The research in this thesis involves both paradigms and instead of a linear progression of knowledge creation, the research is formed through the interplay of theoretical and empirical insights (Carlile & Christensen 2005). The author of this thesis has through out his PhD project engaged himself with scholars and practitioners much in the manner described by Van de Ven (2007). Much social and organisational research is characterised by a gap between theory and practice. Academics rarely attempt to put their theories in practice and practitioners rarely report and relate their experiences to theory. Given this poor state of interaction between research and practice, Van de Ven proposes that research should be an engaged form of inquiry where researchers involve others and leverage their different perspectives to learn about a problem or phenomenon. In this way the likelihood of advancing knowledge for academia and industry increases by engaging with practitioners and other stakeholders. Van de Ven shows how this can be achieved by constantly iterating between theory building and theory testing in practice (see Figure 3.3).

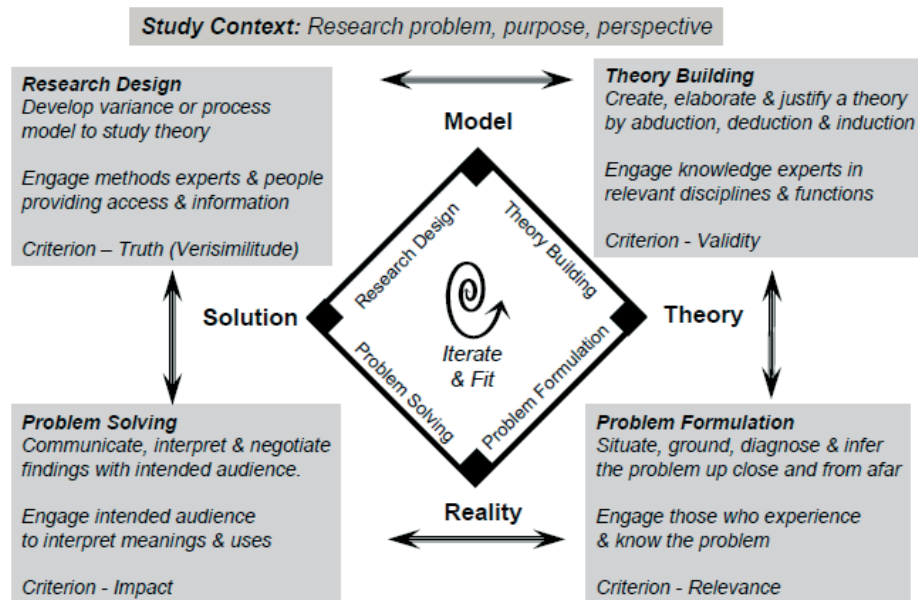


Figure 3.3 A model for engaging with practitioners and scholars in iterative four steps (Van de Ven 2007).

Robson (1993) describes three purposes for carrying out research: *exploratory*, *descriptive* and *explanatory* (see Table 1.7). As not much research has been done in the context of PSS in Engineering Design, the main purpose of this research is to explore PSS based on the current understanding of Engineering Design and Product Development and

attempt to build a theory of the synthesis of PSS. It is apparent from the above that the nature of this research is to seek new insights and assess PSS from a systematic design perspective. The research strategy in this project is therefore mainly exploratory in order to contribute to theory building (Eisenhardt 1989).

Exploratory	Descriptive	Explanatory
<ul style="list-style-type: none"> - To find out what is happening - To seek new insights - To ask new questions - To assess phenomena in a new light - Usually, but not necessarily, qualitative 	<ul style="list-style-type: none"> - To portray an accurate profile of persons, events or situations - Requires extensive previous knowledge of the situation to be researched or described - May be qualitative and/or quantitative 	<ul style="list-style-type: none"> - Seeks an explanation of a situation or problem, usually in the form of causal relationships - May be qualitative and/or quantitative

Table 1.7 Three purposes for carry out research (Robson 1993).

Research is typically characterised as either *qualitative* or *quantitative* (Yin 1994; Creswell 2007). As this research does not seek to prove a theory but rather gain an understanding of PSS to build a theory of synthesis, it is in principle qualitative. It focuses on the nature of the relationships and interplay between different elements of PSS. Qualitative research is done by inquiring into a phenomenon by considering it from multiple perspectives and uncovering its many dimensions to provide a complete understanding. Although it is difficult to generalise insights based on qualitative research, it can lead to identifying new patterns and themes that can later be investigated further through quantitative research (see Table 1.8).

Qualitative research	Quantitative research
<ul style="list-style-type: none"> - Mainly used to develop an insight into the nature of a specific subject. - Often involves a deeper analysis that helps build an understanding of how elements are arranged. 	<ul style="list-style-type: none"> - Often used to verify a hypothesis - Done by measuring, testing or categorising elements in ordering to describe or explain something.

Table 1.8 The characteristics of qualitative and quantitative research (Creswell 2007).

3.3 Research methodology

Blessing and Chakrabarti (2002) propose a systematic methodology for conducting Engineering Design research. Design Research as a research field is peculiar compared to much other research in that it is not only concerned with what is, but also with what ought to be. A characteristic of Design Research is the numerous influencing factors and their interconnectivity. This makes it difficult to separate factors from each other and determine causality. Given these conditions Design Research appraises '*usefulness*' as much as it does '*validity*' (see section 3.5).

The proposed Design Research methodology is as follows (see also Figure 3.4):

1. **Criteria Definition**

Define the objective and focus of the research and then find factors that contribute or prohibit the improvement of the aspect of design that is in focus. This is done by setting up success criteria (overall objective of the research) and measurable criteria (the criteria that is possible to determine in the research).

2. **Descriptive Study I**

Identify factors that influence the measurable criteria and determine how they influence these. Then form a basis for the development of design support.

3. **Prescriptive Study**

Develop a model or theory describing how the design support improves the design or design process. The design support is then evaluated as a tool or method.

4. **Descriptive Study II**

Identify whether the design support can be used for the situation it is intended for and it does address the factors it was supposed to address.

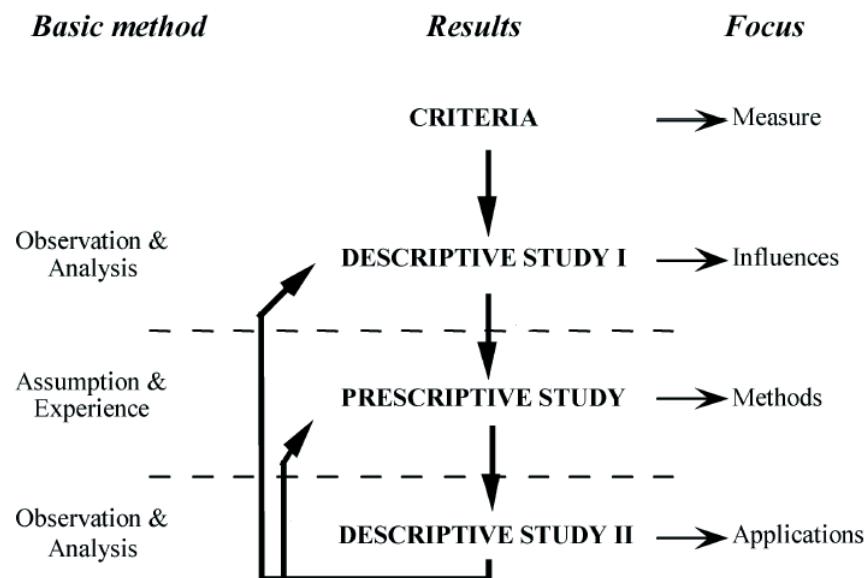


Figure 3.4 The Design Research Methodology framework applied in this thesis (Blessing & Chakrabarti 2002).

Blessing and Chakrabarti do however note that most research projects only focus on one or two of the above stages and that iterations do take place between each step. This thesis began with the definition of the objective and focus of the research (success criteria), but when it came to setting appropriate measurable criteria for whether the research actually does lead to better understanding of PSS design and improved strategies and methods for PSS development, this was difficult to do. In the absence of concrete measurable criteria, the researcher engaged with other PSS

design researchers and the actors involved in the case studies as described in Van de Ven's model (see Figure 3.3). During the research project the researcher asked them of their perception of the proposed models for understanding PSS and the usefulness of the PSS design methodologies. Based on these discussions and feedback the researcher reflected on the process and outcomes of the research and in this way could draw conclusions on whether the research actually contributed to its initial objectives.

Based on the proposed Design Research Methodology, the general outline of this PhD project is as follows:

1. ***Criteria Definition***

Based on an initial literature review on PSS and discussions with individuals from industry and other researchers in the field, the project's objective and focus of research was first defined (see Chapter 1). A set of preliminary research questions were formulated and this directed the ensuing literature review (see Chapter 2).

2. ***Descriptive Study I***

The first part of the research relates to comparing PSS with the existing knowledge in Engineering Design and Product Development. This is in essence exploring the application of a theoretical framework (Engineering Design) to a new domain (PSS). The literature on Engineering Design, Product Development, Service Marketing and PSS was reviewed to form a conceptual framework for understanding PSS from a design perspective (see Chapter 5).

3. ***Prescriptive Study***

The theoretical framework was then applied onwards in the research and confronted with empirical observations. This represents the second part of the research which relates to the conceptualisation of PSS. Building upon the theoretical framework of PSS synthesis, a design methodology for PSS was proposed. This methodology was then applied in student design projects and together with companies (see case studies in Chapter 4). The observations were then reflected upon to evaluate their appropriateness and applicability to PSS design (see Chapter 6).

4. ***Descriptive Study II***

The last part of this PhD project aimed to determine how PSS may be developed in manufacturing companies. Here the theoretical framework was used again in relation to a company context in order to understand the relationship between PSS design, market conditions, the organisation and strategy (see Chapter 7).

The research in this thesis was mainly focused on identifying the main factors that influence the successful design of sustainable PSS (Descriptive Study I), and developing a theoretical framework for the PSS

design and development (Prescriptive Study). The second Descriptive Study, where the idea is to evaluate whether the proposed theoretical framework does indeed contribute to success, was executed less in depth. Due to the limitations of time and resources in the PhD project, it was not possible to perform a detailed evaluation of the results of the research, but as mentioned an initial review was done and the findings reflected upon.

3.4 Research strategy

There are many different strategies that can be applied to studying a phenomenon in research. This PhD project has used a variety of sources and methods for gathering information and understanding the research object. In the following these methods are presented.

3.4.1 Theoretical approaches

Literature review

As this thesis takes the existing theoretical knowledge in Engineering Design and Product Development as the point of departure, literature is an essential source of information. The researcher already had a firm knowledge of the key literature in Engineering Design (particularly those based on the informally constituted international Engineering Design society: WDK (Workshop Design-Konstruktion) community) and Product Development (including product innovation) and therefore the initial search for literature focused mainly on the past decade's environmentally-oriented publications on PSS and related terms. Product life thinking was a common trait to this literature. In parallel with the PSS literature, the business literature on *Servitization* and *Integrated Solutions* was scrutinised. The literature on the design and development of services was then consulted to see how it differed to the product-based literature. Here particularly *Relationship Marketing* provided insights to customer activities and value perceptions. A lot of the literature studied dealt with the strategic and organisational aspects of service-orientation in companies, so the literature on *strategy formulation*, *business development* and *value networks* was also studied. Finally the review circled back to product-oriented service design methods found in the manufacturing literature on *maintainability* and *supportability*. The above is a general retrospective description of the literature review. The actual review was not as structured and literature was uncovered and studied throughout the entire PhD project (and sometimes even re-discovered and consulted in relation to new observations). The literature sources were very varied. The majority of the literature was accessed from academic publications (e.g. Journal of Cleaner Production, Harvard Business Review, European Management Journal, etc.), conference proceedings, books and doctoral theses. In addition a fair amount of literature was reports from professional organisations (e.g. United Nations Environmental

Programme, European Union, various governmental departments, etc.) as well as articles from consultancy firms (e.g. McKinsey, Deloitte, Booz Allen Hamilton, etc.), popular magazines and company publications. When reviewing the literature, critical attention was given to the type of literature and how the insights were reached.

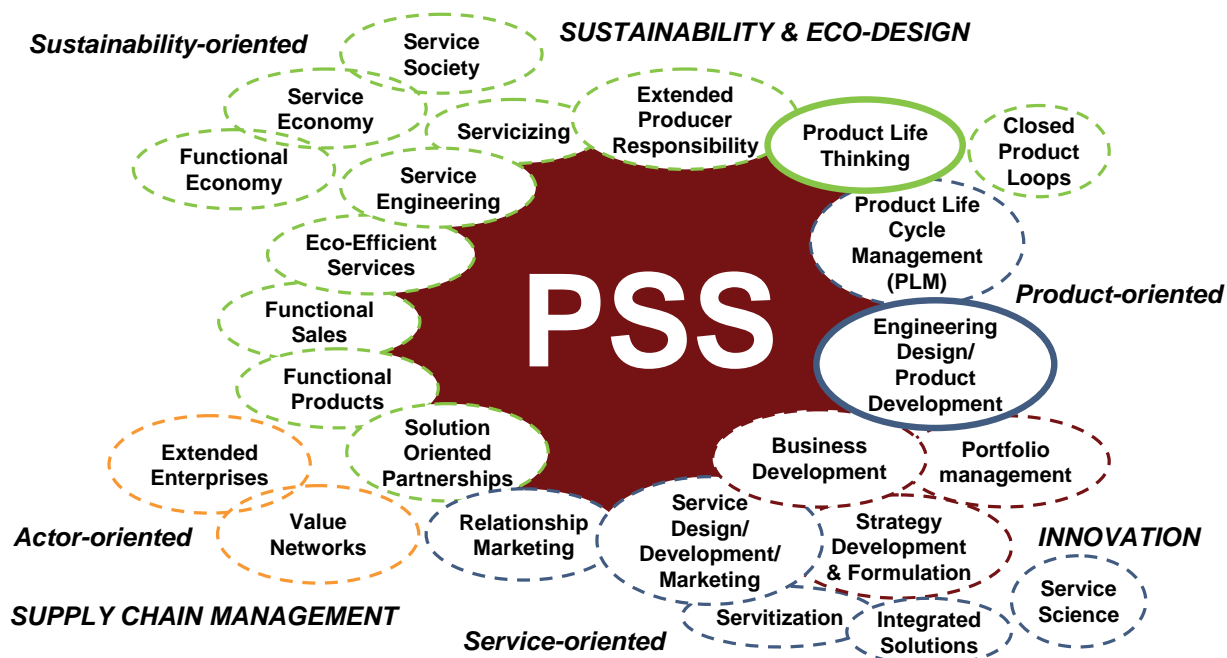


Figure 3.5 An overview of the theoretical foundation and reviewed literature in this thesis (see Chapter 2 for a detailed review of the different terms).

Academic discussions

Critical rationalism encourages researchers to confront and discuss their findings and insights with other researchers and practitioners. Besides his supervisors and closest research colleagues the author also engaged in conversations with other researchers through visits, seminars, workshops and conferences. The following are just some of the occasions where the author has discussed his research with other academics.

Conferences

- DESIGN 2006, International Design Conference, Dubrovnik, Croatia, May 19-22, 2006
- Integrated Product Development Workshop (IPD 2006), Magdeburg, Germany, October 28-31, 2006
- ICED '07, International Conference on Engineering Design, Paris, France, August 28-31, 2007
- Research Conference on Relationship Marketing and CRM, EIASM (The European Institute for Advanced Studies in Management) Brussels, Belgium, November 28-29, 2007
- CIRP IPS2 Conference 2009, Industrial Product-Service Systems, Cranfield University, UK, April 1-2, 2009

Workshops and symposiums

- Nordic workshop, "Product/Service-Systems," Technical University of Denmark (DTU), December 6, 2005
- Workshop, "Product/Service-Systems," Technical University of Darmstadt, February 13-14, 2006
- Workshop, "Service Engineering," Technical University of Darmstadt, May 28-29, 2006
- Workshop, "Product/Service-Systems (PSS)," Technical University of Denmark, November 20-22, 2006
- Workshop, "Integrated Product and Service Engineering," Linköping University, May 29-31, 2007
- Workshop, "PSS Design Research," Luleå University of Technology, October 26-27, 2007
- Symposium, "Service Design," Copenhagen Institute of Interaction Design, March 6-7, 2008
- Symposium, "Developing Sustainable Approaches to Design-Make-Serve," University of Cambridge, July 5-6, 2008

Visits

- Center for Innovation in Product Development, Massachusetts Institute of Technology (MIT), May 10-11, 2007
- Department of Product Design, Norwegian University of Science and Technology (NTNU), March 29, 2007
- Visiting researcher at the Institute for Manufacturing, University of Cambridge and the Manufacturing Department, Cranfield University, March - July, 2008
- The Innovative Design & Manufacturing Research Centre, University of Bath, May 14, 2008

3.4.2 Empirical approaches

Case study

As the aim of the research was to gain explorative, qualitative, real-life insight in order to build theory, *case study research* was seen as the most appropriate research strategy (Yin 1994). Case study research allows a phenomenon to be investigated within its real-life context and reveals the relations the research object has to other elements. In case study research multiple sources of information collection techniques are used, e.g. observation, interviews, document analysis, etc. The information gathering process in case studies is thereby flexible and allows new themes and insights to emerge during the process (Eisenhardt 1989). Case study research as an *action researcher* or *participant observer* was the most dominant research method used throughout the PhD project. The researcher in this manner is not an 'objective' observer of the occurring phenomenon and therefore risks being biased in his observations, but as the aim of this research is to explore the development activities of a company, emphasis is placed on being present during the development

process and not just in formal, periodical project meetings. This type of research strategy gives a deeper understanding of the development project and its context in the company, as well as it provides better access to all relevant actors when gathering data.

Five case studies were performed in this thesis, each addressing different aspects of the research questions (see Table 3.9 for an overview). Each case study in this PhD project was analysed and written up and the aspects related to the research questions were identified and used as evidence (see Figure 3.6). A brief description of the each case study can be found in the following chapter (Chapter 4).

Case study	Organisation	Size	Location	Type of business	Core offering	Main method for gathering information	Duration of study
A PSS Design Course	University	Approx. 45 students in the course	Denmark	Education	Engineers (B.Sc. & M.Sc.)	Action research using PSS design methodology in a course setting	2 x 13 weeks (Sep – Jan 2006/ 2007 & 2007/2008)
B Steelcase	Manufacturer	Large (< 500 employees)	USA & France	Mainly business-to-business	Office furniture	Participant observer in a development project	15 months (Oct 2006 – Dec 2007)
C Vitsø	Manufacturer/ Design firm	Small (> 50 employees)	UK	Mainly business-to-consumer	Shelving systems	Action research using PSS design methodology in workshop meetings	3 months (May – Jul 2008)
D RiverSimple	Technology entrepreneur	Small (> 50 employees)	UK	Mainly business-to-consumer	Hydrogen car	Action research using PSS design methodology in workshop meetings	2 months (June – Jul 2008)
E SCA Hygiene Products	Manufacturer	Large (< 500 employees)	Denmark	Mainly business-to-government	Incontinence products	Interviews and workshops	3 months (Nov 2008 – Jan 2009)

Table 3.9 A summary of case studies performed in this PhD project (see Chapter 4 for a detailed description of each).

3.4.3 Data Analysis

The data analysis in this PhD project was done in parallel with the information collection. Based on the collected evidence that was stored in personal notes, tape-recordings, various documents, etc., the information was distilled and structured in spreadsheets chronologically, which formed a narrative (Robson 1993). When possible supporting evidence (e.g. slide presentations, press releases, etc.) was linked to an observation. Then based on themes uncovered in the literature, the information was marked out accordingly. New themes emerged in this process as the empirical data provided other insights. This approach corresponds to the pattern-matching strategy for analysing data (Yin 1994). Each case study was then framed by writing up the case based on a structure given by the theoretical framework. This was done to allow the case studies to be more easily compared and be related to the existing literature. Reflections

were made on each case and how it related to the research questions. Figure 3.6 shows how the various sources provided insight to each research question. In this way the theory in this thesis could be challenged, not on its ability to make predictions, but rather on how well it integrated, interpreted and made sense of the collected empirical evidence.

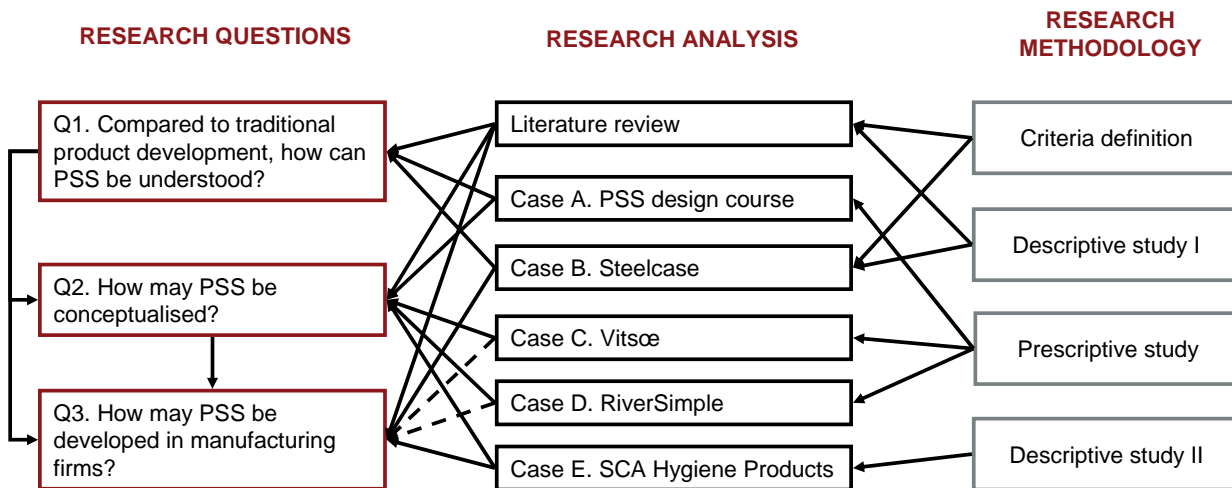


Figure 3.6 A representation of the flow of research and how different sources are used as a basis for analysis in relation to the research questions. Also shown is how the research methodology formed the role of the literature review and case studies.

Industry conversations

A criticism to researchers in the applied sciences, design being one of them, is that they often fail to bridge the gap between theory and practice, and do not adequately engage with practitioners (Van de Ven 2007). To amend this and follow in the spirit of critical rationalism, the author confronted and discussed insights from the PhD project with industrial practitioners. The following are examples of events where the author has interacted with individuals from industry.

Workshops

- CIPU workshop, "Development of Product/Service-Systems (DTU)", Technical University of Denmark (DTU), June 28, 2005
- CIPU workshop, "Product/Service Thinking as an Innovation Strategy", Development of Product/Service-Systems (DTU)", Technical University of Denmark (DTU), March 13, 2007

Industry conferences

- Product Development Day, "Globalisation of Product Development", Technical University of Denmark (DTU) & IPU Development, December 7, 2005
- Product Development Day, "Users – Technology – Service – Knowledge", Technical University of Denmark (DTU) & IPU Development, December 6, 2006
- Innovation Lab, "CustomerMade", IT University, April 20, 2006

- Product Development Day, “Product Innovation”, Technical University of Denmark (DTU) & IPU Development, December 5, 2007
- Product Development Day, “System in Product Development”, Technical University of Denmark (DTU) & IPU Development, December 3, 2008

Company visits

- PBI Dansensor A/S, April 26, 2006
- Aarstiderne.com, February 9, 2006
- Steelcase, September 2006 – October 2008
- Gabriel A/S, February 5, 2008
- Vitsø, May – July, 2008
- SCA Hygiene Products A/S, October 2008 – March 2009
- Danfoss A/S, January 15, 2009

3.5 Research quality

The research methodology chosen in this thesis is not without flaws. As Design Research has more in common with social studies than the natural sciences, it is problematic to use an “ideal” (positivistic) scientific method (Checkland & Holwell 1998). Buur (Buur 1990) makes the point that theoretical contributions in Design Research are almost impossible to verify and prove empirically, as the design process is stochastic in nature and the large number of influencing factors are impossible to regulate. It is therefore difficult to provide validity of research results in the traditional sense. There are however ways in which theoretical contributions may be verified by qualitative means. The following describes how the quality of the research is ensured.

3.5.1 Validity of empirical findings

Yin (1994) proposes four criteria on which the quality of empirical research should be judged upon:

- *Construct validity* refers to the manner in which theoretical concepts are understood, observed and measured in a study
- *Internal validity* refers to whether causal relationships may be determined between events
- *External validity* refers to whether the research findings can be generalised
- *Reliability* refers to whether the research methodology allows another researcher to conduct the same case study and would arrive at the same results.

Each of these criteria was considered when preparing and conducting the case study research. The researcher made efforts to ensure that evidence was collected from multiple sources and that the data collection and data analysis process was as transparent as possible. The quality and validity of the research in this thesis is discussed in more detail in Chapter 8.

3.5.2 Theoretical verification

A large part of this thesis deals with building a theoretical framework for PSS. To help in this process, Buur (1990) suggests two types of verification of theory.

- *Logical verification* is achieved by ensuring *internal* and *external consistency* as well as *completeness*. Internal consistency refers to the principle that the individual elements of the theory should not conflict with each other. External consistency relates to whether the theory is in agreement with existing well-established and successful methods and theories. Completeness refers to that all relevant phenomena can be explained or rejected by the theory.
- *Verification by acceptance* is achieved by a *relevant scientific community* recognising its contribution to knowledge and that the descriptive models and methods derived from the theory are acceptable to *experienced practitioners* (e.g. designers, product developers, etc.).

Logical verification has been sought after by acknowledging and respecting existing and well-established concepts, theories and methods found in literature. Regarding internal consistency and completeness, the research in this thesis is actually an attempt to expand and complement the existing knowledge in Engineering Design with the new characteristics of PSS. Verification by acceptance was tested by the active participation in the many academic conferences, workshops and seminars (see section 3.4.3). Here it was observed that elements of the research in this thesis have already been referenced and adopted by other researchers in the area (Gegusch et al. 2009; Meier & Krug 2009). The methods developed in this thesis were tested in some of the case studies. This allowed the researcher to assess the acceptance of the models and methods by practitioners and their perception of the usefulness of them.

3.6 Summary

In this chapter the research methodology and its premises have been described. This PhD project operates in the field of Design Research which implies certain characteristics of how the research is approached. This is summarised as follows:

- The research purpose is two-fold, to understand and improve the phenomenon.
- The philosophical approach used to gain knowledge is predominantly interpretative.
- Both problem-based and theory-based approaches are applied and both scholars and practitioners have been actively engaged throughout the PhD project.
- The research is characterised by being mainly exploratory and qualitative to contribute to theory building.

- The research methodology has been formed by the research objective and research questions.
- The research strategy is largely based on literature studies and five empirical case studies and each of these have been related to each individual research question.
- The protocol (i.e. case selection, role of the researcher, data collection and analysis, etc.) for both the empirical and theoretical research approaches were described and discussed in relation to validity and verification.

4 Case studies

This chapter provides a brief description of the five case studies that the research in this thesis is based on:

1. Case study **A: PSS Design Course**
2. Case study **B: Steelcase**
3. Case study **C: Vitsø**
4. Case study **D: RiverSimple**
5. Case study **E: SCA Hygiene Products**

Chapter 3 described how the researcher gained access and gathered information in each case. Each case study here consists of:

- an introduction and background;
- how the data for case study was gathered;
- a description of the business;
- a description of current products and services;
- a description of development activities; and
- an explanation of how it relates to PSS.

The aim here is to give the reader a broad understanding of each case and the context in which the observations were made. In the ensuing chapters the case studies are revisited and addressed more in detail in relation to the research questions posed in this thesis.

4.1 Case study A: PSS Design Course

The first case study covers the use of a proposed design methodology for PSS in a university course setting. The author was involved in the planning, teaching and evaluation of a PSS design project course (course number 42050) at the Technical University of Denmark (DTU). The course is aimed at third year engineering students on a relatively new (launched in 2002) design engineering Bachelor-Masters programme, but also open to students on other curricula. The objective of the course was to give students experience in using tools for product life design through a project based on a product or service system case. At the start of the course students were given a product or activity which they had to analyse to determine its main environmental impacts. They were then asked to conceptualise a PSS solution that provided the same function or benefit with considerable less impact on the environment. The course was a fitting opportunity to develop and apply a methodology for PSS conceptualisation.

The duration of the course was 13 weeks (a whole semester) and is supported by a theoretical course in product life and environmental issues (DTU course number 41051). On average 45 students attended each year. The PSS design project is allocated in the students' timetable to a whole day once a week throughout the semester, where the teachers

give short presentations and exercises but otherwise allow the majority of time to be used for project work and supervision. The students are asked to form groups of approximately six and share a class room/project space. The students are expected to spend on average 14 hours a week working on the PSS design project (corresponding to 10 ECTS points).

The author was involved with the course over three semesters (autumn semester 2005-2007). The first semester (autumn 2005) merely as a teaching assistant supervising student projects (16 projects with 2-3 students in each). The other two semesters (autumn 2006 and 2007), he was jointly responsible for the planning, teaching and evaluation of the course together with two other teachers (6 & 8 projects respectively in 2006 and 2007). The student projects were evaluated each year internally by the teachers themselves and externally by a censor from industry. Furthermore project sponsors (e.g. manufacturers and city council) provided feedback to the students at the end of the course.

Action research (Checkland & Holwell 1998) best describes the manner in which the case study was approached. Evidence was gathered through weekly interactions with the students and supported by all course materials, student work and assignments, course evaluations and student reflection reports. The author's reflections were complemented with the impressions and reflections of the other teachers. Personal notes and materials produced during the course formed the main documentation of the case study. For additional information on this case study, see (McAloone 2006; McAloone 2007; Tan et al. forthcoming).

4.1.1 The business (or rather course assignment)

The students in the course were asked to take an existing product or service activity as a point of reference and then propose new PSS-oriented solutions that are capable of providing the same (or better) benefits whilst radically reducing the systems' environmental burden. Focusing only on design changes in the technical product usually only results in limited improvements, but changing infrastructure and user behaviour has the potential for much greater improvements (Brezet et al. 1999). The students were encouraged to identify not only changes to the product, but also changes that could be made to the entire production and consumption system as well as how stakeholders' motivations and incitements could be aligned when searching for solutions. The majority of students in the course were from the new design engineering curriculum at DTU and were therefore used to design projects and design thinking. They were also taught throughout their curriculum to consider and analyse the socio-technical aspects of products and their use, based on Actor Network Theory (Latour 1991). They were, however, novices in the life cycle aspects of products and service design.

The product and service examples (see Table 4.1) in the course were provided by different organisations each year (i.e. manufacturers, the university and the local municipality). This gave the design projects a ‘real life’ context which allowed the students to gain access to individuals in the organisation and actual users in each case. Besides the interest in innovative environmental solutions the providing organisations did not dictate the design direction in the students’ projects, but allowed them to generate ideas freely. At the end of the course the students presented their ideas and conceptual solutions to the involved organisations and received feedback on their work.

4.1.2 The products and services

The focus of the product/service application areas were deliberately altered each year, in order to test the design methods on different applications (see Table 4.1).

Course year	Project theme	Example of reference products
2005	Products related to food preparation	<i>dishwasher, electric oven, electric stove, food processor, freezer, kettle grill, terrace heater</i>
2006	Activities on campus	<i>text book, campus commute, lunch, printing, student accommodation, clothes washing</i>
2007	Local municipal services	<i>dishwasher (water), lamp post, printed material, road, rubbish truck (waste), shower (water), skip (waste), toilet (water)</i>

Table 4.1 Different product and service themes were used as the starting point for PSS design in the course.

Characteristic for the reference products in 2005 was they were all related to food preparation, but they were also all energy-using products that have the greatest environmental impacts in their use phase. In 2006, it was not so much a product that was used as a starting point, but rather the students themselves as users and their daily activities at the university. The basis for the PSS design projects in 2007 was the technical services that are provided to citizens in the local municipality. This represented a different type of reference product to be addressed with PSS approaches as they were related to basic infrastructure systems (e.g. waste management, roads, water supply, etc.).

It would be too extensive to provide a full list of the 30 PSS design projects performed over the three years, so instead three examples of student generated PSS concepts are provided to give an idea of the types of solutions that were conceived:

- *From freezer to freezing and food delivery system* (Student project 2005)

Using a household freezer as the reference product, students developed a PSS system for residents in apartment buildings. Instead of each apartment having sizeable freezers of their own, a communal freezing room in the apartment building would offer

more efficient freezing capacity as well as allow food retailers to provide a frozen food home delivery service. This PSS concept might not eliminate the demand for a freezer in each kitchen – ice cubes and other items need to be conveniently accessible – but it would reduce the size needed of each individual freezer and increase the total energy efficiency (as well as provide more space in the kitchen). At the same time due to the centrally located freezing room, food delivery services could be provided more safely and efficiently. Furthermore, residents would benefit from the convenience of home deliveries and avoid the transport of frozen goods. The proposed PSS would entail a new form of collaboration between building construction companies, building owners, refrigeration equipment suppliers/manufacturers and food retailers, but each would be able to benefit from this new system. This PSS concept introduces a new way of food delivery and storage that involves changes in the product (individual freezer and the freezing room), customer activities and the relationships between the involved companies.

- ***From canteen lunch to food ordering system*** (Student project 2006)
A study into the lunch meals served everyday in the university's canteens led to students proposing a food ordering system that would support the chef when planning meals. A chef of a canteen has to be able to serve many tasty, nutritional dishes at a reasonable price within a short lunch break. It is challenging enough to balance these constraints without having to consider environmental impact issues. Currently, the chef's choice of recipe and ingredients are mainly based on costs when ordering food. After discovering that the choice and amount of each ingredient are the main determinants of a dish's life cycle impact, the students developed a food ordering system that could automatically calculate and correlate the cost, nutritional value, and environmental impact of a recipe (see Figure 4.1). The system would automatically suggest alternatives for ingredients to allow a more nutritious, cheaper and/or more environmental choice to be made. Integrated into the system was also a customer satisfaction survey that could provide feedback on the dishes served. This system could be offered by wholesale caterers to help their canteen customers guide food purchases in a more cost effective, nutritional and environmentally friendly manner. The greatest effects – whether cost, quality, nutritional value and environmentally – of a meal are determined when choosing a recipe and ordering food. This PSS concept supplies the chef with all relevant information about costs, customer satisfaction the last time the meal was served, nutritional value and environmental impact, and suggests alternative ingredients if any of the effects could be improved. Here the PSS concept addresses the defining moment and considers the actor (cook), the activity (ordering ingredients) and the actor network (wholesale food suppliers and customers).

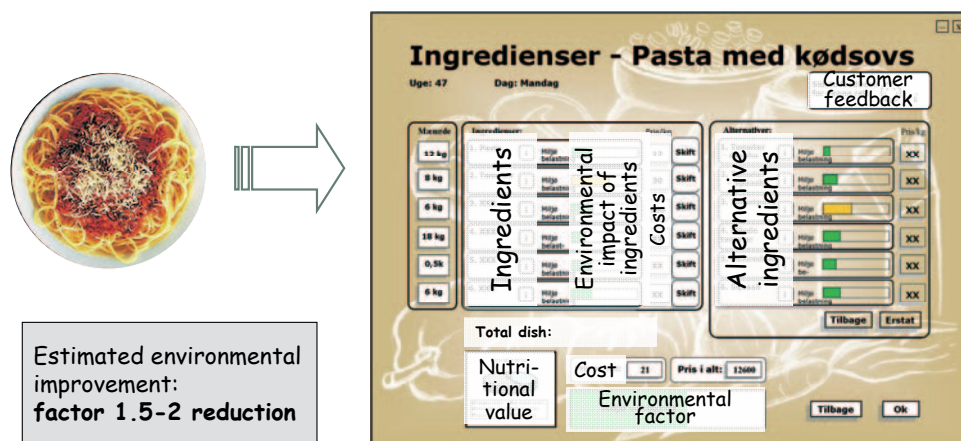


Figure 4.1 An example of a PSS design concept. From a university canteen's lunch to food ordering system that correlates costs, nutritional value, environmental impact and customer feedback of the served dishes. The system also suggests alternative ingredients for recipes if costs, nutritional value or environmental impact could be improved (student project 2006).

- *From street lighting to on-demand lighting* (Student project 2007)

The municipal street lamps along roads and paths are lit from dusk to dawn to provide light for the safety and security of traffic and residents, but in a lot of areas these street lights are left on throughout the night without any need for them. Using existing technologies for energy, lighting, sensors, information and communication, the students developed a PSS concept that would be able to adapt to the users' needs for light at night. This would potentially reduce the light pollution and energy consumption in the municipality without compromising safety and security. The actor network of this PSS included the electricity company, which would develop, implement, operate and maintain the new flexible lighting system based on an agreed level of lighting functionality for a fixed fee. This configuration was thought to motivate the electricity company to invest in the more energy efficient technologies and ensure that only the light that was needed was delivered. The on-demand activated lighting system would also allow residents to 'personalise' the lighting of their own neighbourhood. This PSS points at the gross inefficiency of an everyday system where what is provided, far exceeds what is actually needed. It represents a considerable potential for reducing energy consumption by matching the utility with demand through better understanding of residents and their need and usage of street lighting.

In general the PSS concepts generated by the students were deemed to be quite innovative among both the teachers in the course and the external examiners. As the three examples presented above show, the design ideas go beyond that of traditional product design. The students on the design engineering curriculum were well trained in graphical visualisation techniques. This made it very easy for them to communicate their ideas to others so they were quickly understood. It

would of course take considerable effort to implement many of the PSS concepts proposed in the course. Indeed more than just bringing a new product to market, as they often involved new types of collaboration or changes to existing business models. Nonetheless most of the PSS concepts did seem viable and economically feasible.

4.1.3 The development activities

At the start of the semester each student group was given a physical product or access to an activity to analyse and understand its characteristics, properties, actors and context. Based on this they were then asked to design a PSS system that would provide the same benefits and satisfy the original intended needs of the reference product or activity using existing technology at a lower environmental load. The students were given three assignments that served as deliverables for the design project:

1. *Product Life Cycle Gallery* – an analysis of the reference product's life cycle, detailing the environmental effects, actors and stakeholders, customer activities, DfX impacts, trade-offs and dispositions (see Figure 4.2).
2. *Analysis, Diagnosis, Focusing & Goal Setting* report – a summary and conclusion of the Product Life Cycle Gallery with different scenarios and opportunities investigated to determine which solution strategy would result in the best environmental improvement.
3. *PSS concept description* – a slide presentation, marketing brochure, posters and short report explaining the PSS concept; the value proposition; the products and services offered; the actor network; user and use scenarios.

The students were asked to describe the entire PSS, i.e. the products; the services; the actors involved; and how the whole system was connected. In addition they had to provide reasoning for the advantages for the customer or user, the business potential, and the environmental benefits. In particular they had to account for the changes made to the existing system whether it was the product, the services, or the actors involved, and how these changes allowed the environmental benefits to be achieved.

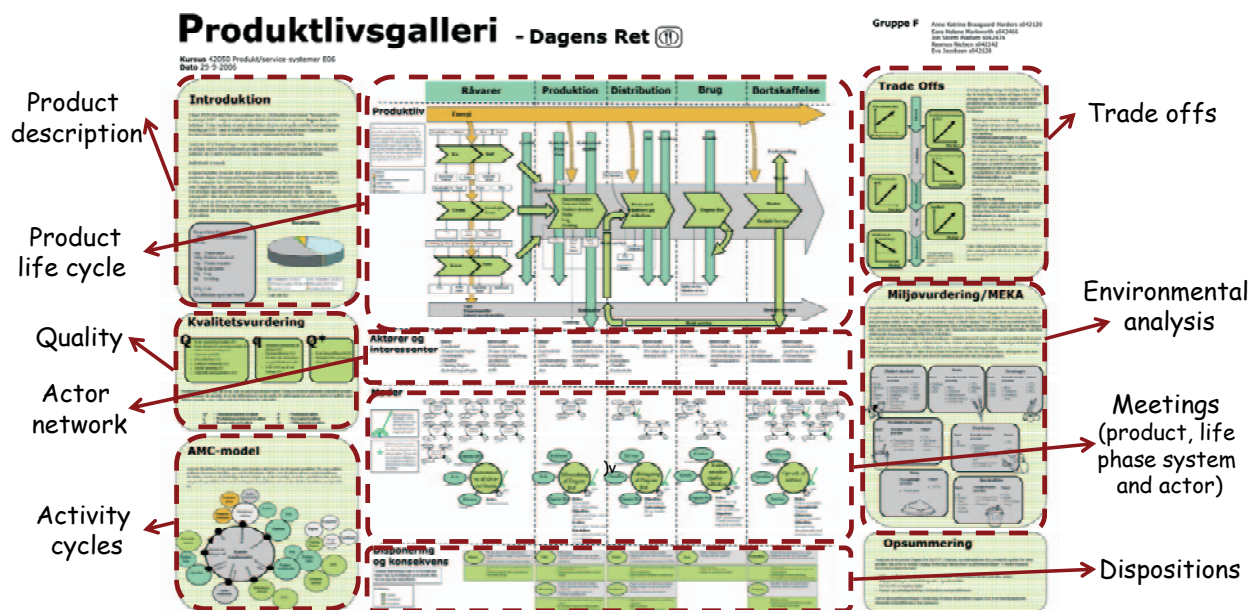


Figure 4.2 An example of a Product Life Cycle Gallery for a 'meal of the day' at the university canteen. The poster provides an overview of the analysis of the reference product, its life cycle systems, use scenarios, stakeholders, environmental impacts, etc. (Student project, 2006)

4.1.4 PSS implications

Naturally the PSS design course deals with PSS design, although it is in a limited context of a student design project in a classroom setting. However, this case study has allowed the teachers and researchers to explore different aspects of the conceptual design of PSS. Although the objectives and main components of both courses were consistent for 5 years, the course and the design methodology was refined each year. This happened in dialogue with the students, colleagues and the external industry examiners. Based on an approach to life cycle thinking borrowed from Eco-design and other DfX methodologies, the actors along the product's (and auxiliary product's) life phases were identified and their activities and behaviour studied. This provided the students with a good understanding of where in the system changes could be made (or at least influenced), so that it would result in improved systems that were less harmful to the environment.

4.2 Case study B: Steelcase

The second case study is based on a research project performed in collaboration with a large global office furniture manufacturer. The author was offered the opportunity to work as a (paid) consultant on one of the company's development projects. The objective of the project was *"to develop a computer based information system linking workspace design with business results and sustainability performance (in economic, environmental and social terms) to support decision making when planning office workspace"*. The ultimate aim of the project for the company was to actively engage their clients in workspace planning by demonstrating that their physical office workspace has economic, environmental and

social impacts vital to their strategy and business performance. The project was aimed at the company's corporate consulting team (Applied Research and Consulting (ARC)) and initially seen as the development of a tool for which the consulting team could offer as a service. The author's participation in the development of the project began at a time, where the principal technical foundations had been determined and ended with a working conceptual prototype of the tool – a total of 15 months (Oct 2006 – Dec 2007). During the development project, the author assumed the role of a participant observer using ethnographic techniques to gather and record information. A log book was kept over all project-related interactions. Notes were made intensively throughout the duration of the project. The author participated in 140 meetings and worked over 1000 hours on the project of which 85 days were spent at the company's offices. Throughout the case study supplementary information was gathered from informal conversations about the project, internal company documents, publicly available documents about the company, press releases, and internet searches. This case study provided deep empirical insight to the development activities in a manufacturing company's context and supported the first descriptive study of this thesis.

Steelcase is a global leader in office furniture (Steelcase b). Its mission is *"to provide a better work experience"* which they try to accomplish by offering a multitude of products and services that surround the office workplace environment (Steelcase 2007). The company believes that the physical office workspace environment is a strategic asset (on the same level that people, technology and business processes are) that can be leveraged to support its clients' strategies, and help them achieve their business goals. Steelcase has grown immensely since it was founded in 1912 in Grand Rapids Michigan. Its first products were filing cabinets and safes. The corporate portfolio has grown to also include subsidiaries that offer upholstery textiles and fabrics, lighting solutions, IT network cabling, visual communication products and even complete turnkey office buildings. It has also expanded their customer base to include educational and health care institutions. In 2007 it had 13,000 employees globally covering eight business units: the Steelcase Group (serving USA and Canada), Turnstone (low cost office furniture), Nurture by Steelcase (healthcare work environments), Steelcase International (serving the rest of the world), Design Group (premium design textiles and furniture), PolyVision (visual communication products), IDEO (design consultancy) and Financial Services (leasing services) (Steelcase 2007). This case study is based on a global development project involving the Steelcase Group and Steelcase International as well as a joint venture company, Workstage that designs and constructs turnkey office buildings (www.workstage.com). For more information on this case study see (Tan et al. 2007) and (Tan et al. 2009).

4.2.1 The business

Steelcase operates mainly in the business-to-business and business-to-government (public sector) market and has a strong global presence supported by independent and company owned dealers throughout the world. Although its market position is strongest in North America (60% of total revenue in 2007). The company is usually associated with high quality durable products that take environmental issues seriously. Steelcase has a large existing customer base and estimates that its furniture represents the largest installed based in the industry (Steelcase 2007). Steelcase positions itself as a company that understands and is knowledgeable about the way people work in offices in addition to the social aspects of the activities associated with work. This allows it to provide customers with know-how about workspace layout planning.

The office work environment has changed drastically in the past few decades. Work is increasingly information and knowledge intensive; traditional organisational hierarchies have given way to flat, decentralised structures where work is based on projects, teams and networks; and the emergence of information and mobile communication technologies has drastically changed the way people may communicate with each other. This has resulted in 'work' no longer being confined to a particular time or place, but can be performed at any time, anywhere. People today can work from other locations, such as their homes, and flexible working hours allow employees to decide when they want to work. In addition, globalisation has increased the rate at which companies establish and relocate their offices.

The global tendency for a growing part of the workforce to be employed in the service industries implies that global demand for office furniture will also increase. The competitive market situation varies - in North America six leading companies share approximately 60% of the market (Steelcase 2007) whereas in Europe the top ten companies share 30% (Boughnim et al. 2006). The market competes mainly on product design, quality and durability, price, on-time delivery, and service and technical support. But the market is very price sensitive with many competitors delivering comparable designs, quality levels and product features (Besch 2005). Companies typically view office furniture and the physical work environment as necessities that represent costs, which at best contribute marginally to their business performance. Office furniture is seen as something companies must have, but not an investment that pays back over time. Steelcase usually sells to facility managers and purchasers in organisations. These types of customers are typically measured in their own organisation on how good they are at minimising costs while maintaining the same quality level. The effects of the physical workspace environment and how it is planned is usually not valued. Steelcase argues that in office workplaces, employee salaries are

by far the greatest cost to companies and the physical workspace represents just a tenth of the total costs (Harrison et al. 2003). However, the impact of the physical workspace on employees and work, account for a considerable contribution to the companies' everyday business performance.

4.2.2 The products and services

Steelcase offers a whole range of products for the office, educational and healthcare work environments, e.g. chairs, tables, workstations, cabinets, etc. (see Figure 4.3). These products are manufactured in 30 factories around the world and are typically characterised by being long lasting products that require little maintenance. The greatest environmental impacts occur in the raw material extraction and production phases of the life cycle. Office furniture is often disposed of long before its actual functional life is over.



Figure 4.3 Steelcase sells complete office furniture systems (i.e. chairs, desks, panels, storage, etc.). Eco-design is well adopted in the company. The picture shows two product lines: THINK (chair) and ANSWER (workstation). Both have been designed according to the environmental Cradle-to-Cradle certification (McDonough & Braungart 2002).

Manufacturing and the sale of physical products still constitute the majority of the company's activities, but Steelcase also provides a variety of service offerings that support the life cycle of a workspace such as workspace planning, leasing, sales through the internet, reselling of furniture, asset management, ergonomic training, repairs, refurbishment, inventorying, handling moves, as well as strategic workspace consulting (see Figure 4.4).

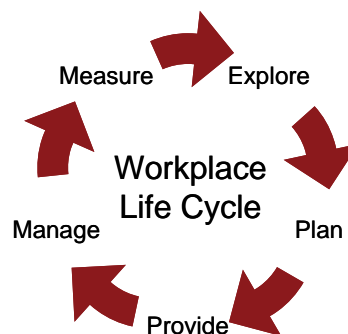


Figure 4.4 Steelcase provides services that cover the entire life cycle of a workspace (Steelcase a) presented in a manner that is similar to Customer Activity Cycle (Vandermerwe 2000).

Most of these services are not limited to Steelcase products, but can entail any brand of office furniture. Recently Steelcase has brought offerings that could serve as exemplars for PSS:

- *Takeback and recycling partnership* with Green Works (www.green-works.co.uk) where redundant office furniture is refurbished and resold to charities, schools, community groups, hospitals and start-up businesses at a low cost.
- *'Eco-lease,'* a leasing of Cradle-to-Cradle (McDonough & Braungart 2002) environmentally certified furniture that are either returned back to Steelcase or purchased after a predetermined period.
- *Office workspace services*, where Steelcase rents out workspace settings and related services on a time basis for as little as three hours (www.workspring.com).

The products and services are sometimes offered as integrated solutions and furniture management services, but at the time of the case study these represented a small part of the business and were mainly targeted to global alliance contracts (major strategic customers).

4.2.3 The development activities

Design and development activities happen on multiple levels and in different functional units of the organisation. The following is a brief summary of some of the arenas where development activities relating to products and services were observed.

Future research and development

Steelcase has over the years built up strong competencies in user-centred design and development. The corporate research group WorkSpace Futures (WSF) studies work, workers and workplaces and uses these insights to create new concept solutions for furniture, interior architecture and technology.

WSF is an executive function to the company's strategic team, and its objective is to carry out early research and application development. Its focus is on understanding users and changing work patterns, as well as the impact of emerging technologies in the workplace. At the time of the case study WSF was organised in groups that cater for ideas and solutions on three different time horizons:

- *Applications LAB* (demonstrate) works on current and immediate research projects;
- *User Insight LAB* (develop) explores business opportunities that lie approximately 3 to 5 years ahead;
- *Innovation LAB* (discovery) investigates trends that look further in to the future (5 to 8 years).

WSF operates globally but the majority of its employees are based in Grand Rapids, Michigan and mostly serve the North American market. WSF's researchers and designers employ well-established design methods and methodologies that were developed together with the renowned design consultancy, IDEO. This approach to design is seen as a key strategic competence to the company and resulted in Steelcase acquiring IDEO in 1996 (LaConte 2008; Steelcase b).

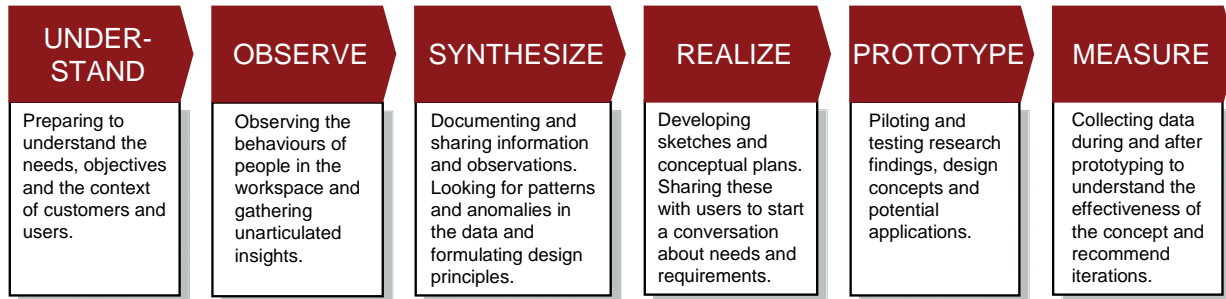


Figure 4.5 Workspace Futures user-centred research and design process (Steelcase d).

The WSF group works broadly both internally in the organisation as well as with many external partners such as universities, think tanks and strategic customers (Steelcase 2007). WSF is committed to ensuring that their research insights and new product ideas are passed on to the rest of the organisation. This can result in new products, workspace settings, services or even new business ventures. For example Nurture, a business venture that caters for furniture for healthcare work environments, was started from insights created by WSF.

Global product development

Work and work environments vary across cultures and markets therefore office furniture products are developed with design teams that understand the local culture and behaviour. Steelcase's product development and design organisations were at the time of the case study based in Michigan, France, Germany and Malaysia (Steelcase b). They are responsible for taking product ideas (either from WSF or their own) and developing them to a market launch. Product development projects are multidisciplinary (R&D, Marketing, Industrial Design, etc.) and are managed through a five-phase stage-gate process. The time-to-market for this process is between 12 to 24 months. Steelcase launches 6 to 8 new products each year in addition to improvements on existing products.

Steelcase is a pioneer in systematically adopting Eco-design methodologies in their product development. Their approach to Eco-design is based on life cycle assessment (LCA), the elimination of toxic substances using Cradle-to-Cradle thinking (McDonough & Braungart 2002), and Design for Assembly (allows more compact packaging) and Disassembly (allows quick refurbishment and recycling) (Azure 2006).

Service development

Most of Steelcase's portfolio of services is offered through their Workplace Services group. The group operates globally but is organised under the North American sales organisation. No formal development process exists for services, but development projects are often initiated with clients based on mutual agreements and then continuously improved. Here benchmarking provides tangible results to demonstrate to customers the performance of their services and the savings achieved. Local dealers also offer a range of services which they have developed individually or with support from Steelcase. An example of this is a take-back service with the partner Green Works (mentioned above) which was launched in the UK. Another part of the organisation that also develops service and new business ventures is WSF. The office workspace service, Workspring, presented above is such an example.

Steelcase also has a dedicated team of (approx. 20) high level corporate consultants called Applied Research Consulting (ARC) which at the time of the case study, was organised under the sales organisation. Corporate consulting began over 10 years ago in Steelcase, but ARC was only formally formed in 2004 when the consultants merged with a team from WSF. ARC helps clients to develop a workspace strategy that supports their organisations' objectives by building upon its understanding of social behaviour in the workspace and user-centred design methods. Depending on how early in the process the ARC team is engaged in projects with clients, they are able to position the value proposition of their services differently:

- *'Transform'* – supporting the transformation of the organisation by leveraging changes in technology, culture, work process and physical space. Here the customer wants to radically change their culture and workspace in order to better achieve their own organisation's objectives.
- *'Redefine'* – supporting the design of a new workspace suited to the way the customer wants their employees to work. This involves significant changes to the workspace.
- *'Refine'* – supporting the current workspace. The customer is interested in moderate change to the workspace to support the way they work.
- *'As Is'* – supporting the sale of furniture, the customer is looking to replace existing furniture and mainly focused on the purchase costs.

The ARC consultants also operate globally and work autonomously as they are typically engaged long before their clients decide on a furniture supplier. The consultants work, and are paid fees, independently of the furniture sales, but a majority of customers do tend to choose Steelcase as their furniture provider if the consultants have been involved early in

the process. The ARC team is capable of guiding clients through the whole process of workspace planning from understanding the current situation and its issues; defining the critical success factors of the workspace strategy in relation to the organisation's objectives; designing the workspace together with employees; as well as performing post occupancy measurement. Although they can operate independently, they often team up with other parts of the organisation, and sometimes also with external architect firms to service customers.

The team has a common approach to consulting (see Figure 4.6) that is based on WSF's design approach, but has no formal development process, as such, for their own services. Their offerings are knowledge intensive so they do continuously learn from their engagements with customers and meet formally at least once a year to share these insights and develop their offerings (Barros et al. 2006). Together with the corporate marketing and communications department, the ARC team has developed research and computer based surveys and tools which they use in their engagements with clients.



Figure 4.6 The ARC's approach to consulting (Steelcase c).

As Steelcase does offer a full range of services, they have at one point also designed and developed them. But this has not happened systematically, and besides the user-centred design approach, there is no formal service development process or global organisation responsible for getting a service idea to market.

4.2.4 PSS implications

At the time of the case study Steelcase already had several solutions that may be called PSS offerings. One could say that the company is already experienced in the design and development of PSS. The management in Steelcase is aware of the challenges of being a furniture manufacturer in the future and the potentials of service-oriented business approaches, but a clear strategy at the time of the research had not yet been formulated. To avoid being caught in fierce price competition with low cost manufacturers, Steelcase has to target higher levels of management in its customer's organisation and demonstrate how the physical workspace can be leveraged to improve business performance.

Steelcase acknowledges that its products and space setting solutions, once developed and installed at customers, are seldom used as intended. A simple example of this is ergonomic features on chairs that are overlooked or misused, failing to realise their benefits. The same applies for space settings that get under or over-utilised. Steelcase realises that it is not enough to simply provide the physical products, but it also has to instruct or encourage certain behaviours as well. This is an issue when launching new workspace concepts. If products or space settings are not adopted in the right way, they will not live up to their true value potential and customers will not be satisfied. Product designers try to make things as intuitive and user-friendly as possible, but often the experience of products and settings is trivial, if not enforced with training, workspace policies or services.

At the time of the study the development of services was being considered in the organisation but without a systematic and integrated approach to the product-oriented business. Steelcase has a close and intimate relationship with many of its customers, but the customer-facing parts of the organisation operate independently from the product-oriented business units. This separation of product and service development allows Steelcase to offer customised integrated solutions, but requires more effort in terms of securing feedback loops from service to product design. Furthermore, employees expressed how different the product-oriented and service-oriented organisations were in terms of business motivation, culture and language. This made it challenging to communicate and collaborate on development projects across the organisation.

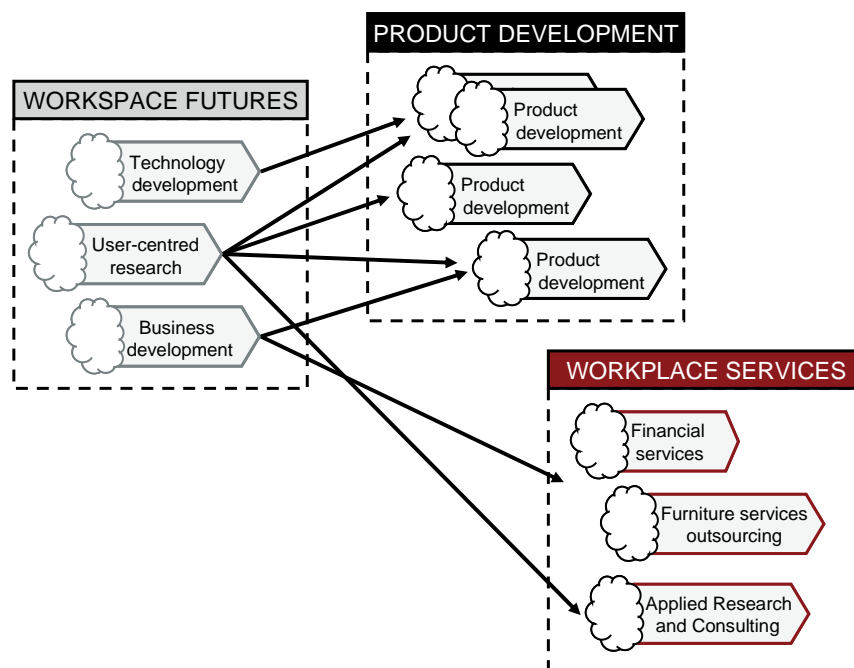


Figure 4.7 Both product development and services are based on a strong user-centred design approach in Steelcase.

4.3 Case study C: Vitsoe

The third case study was performed in collaboration with a small furniture company called Vitsoe. Although Vitsoe's business is based on the sale of products, it does this through life long relationships with its customers. Vitsoe was interested in applying PSS approaches that could extend its existing customers' experience of its products and service capabilities to new customers. The case study was based on a M.Sc. thesis project conducted at Cranfield University (UK) in 2008. Together with the M.Sc. student the author of this thesis arranged four PSS design workshops with two key individuals from the company. The M.Sc. student accomplished most of the project work with guidance and support from the author. Both the student and author took the role of action researchers in the case study. The project lasted three months and resulted in three PSS concepts. During the project additional information was gathered through interviews, visits to the company, accompanying company employees on customer visits, internet searches, company documentation, etc. The author's notes during each workshop with the company and the student's M.Sc. thesis documented the case study. This case provided evidence to the use of the PSS concept design methodology in a company context.

Vitsoe manufactures and distributes high quality furniture designed by the acclaimed industrial designer Dieter Rams (www.vitsoe.com). It is a small design based company that sells its products around the world through partners or directly to customers via the internet. Based on Dieter Rams' "Ten principles of good design", Vitsoe has strong core values on how it conducts business. It aims to provide its customers with better living, "*with less, that lasts longer.*" Although it is a company based on product sales, Vitsoe has a very strong service-orientation and is committed to long-term relationships with customers rather than increasing individual product sales (Vitsoe 2008).

Originally founded in Frankfurt in 1959 by the Danish entrepreneur, Niels Wiese Vitsø, and German furniture-maker, Otto Zapf, the current managing director, Mark Adams, moved the company and production to London in 1995. Vitsoe employs about 40 people including planners that work with customers, production workers and installers (Adams 2008). For more information on this case study see (Gonzalez 2008).

4.3.1 The business

Vitsoe sells mainly to private customers but also caters to the business-to-business market. Its customers are typically design and/or high service centric. At the time of the study most of the revenue was based in the UK (30% of turnover was exported). Vitsoe has a clear business strategy of offering a service and not a product (although it is convinced that it provides very high quality products). Despite this its profits are

generated on the sale of products - not on the extensive services also provided. In many cases the cost of services is included in the sale of products, or if charged separately, it is priced just to cover costs. This service-oriented strategy is successful as half of its business is from existing customers, which considering the durability and long life of the products, is very high. Profit is considered the result of life long relationships and the company attempts to constantly rekindle this relationship. 'Total life cycle thinking' is practised throughout the organisation and short term gains should not compromise long-term expenses. Vitsoe is strongly engaged in the whole life cycle of their products and works with its suppliers to minimise the amount of waste and packaging from supplier all the way to customer (Vitsoe 2008).

The market for design furniture is characterised by low technology developments, a strong focus on individual designers, aesthetics, creative forms and use of materials. Functionality is a given, but it is rather expression and changing trends that dictate the market. Large discounts for products bought in large quantities are common in the furniture industry, but this is discouraged in Vitsoe. Furthermore, employees do not earn commission based on product sales, as this only encourages sales to be based on quantity and not on customer needs (Adams 2008). The aim is for customers to feel they should never buy more than they need, and that they will not be penalised for adding products at a later stage (i.e. it is not cheaper to buy more products in one go than buying them in multiple stages).



Figure 4.8 Vitsoe's product range. Above examples of the 606 Universal Shelving System (left) and the 620 Chair Programme (right).

4.3.2 The products and services

Vitsoe's product ranges comprise a shelving system (designed in 1960) and a chair programme (designed in 1962) both designed by the influential industrial designer, Dieter Rams (see Figure 4.8). The 606 Universal Shelving System (the main product) is a totally configurable system. Backwards and forwards compatibility of the components of the product system has been maintained while the design has constantly evolved. The system and all its parts were designed with longevity in

mind and are easy to construct, repair and dismantle allowing the system to be extended, rearranged and moved. All new components are compatible with the original system. Most of the product is made out of recyclable aluminium, steel and wood, and all joints are mechanical (i.e. not bonded or welded) allowing for easy repair and dismantling. The products enjoy an iconic status, and retain their value well and are even prized on the second hand market (www.designaddict.com). The company also offers to assist its customers when planning, installing, dismantling, reinstalling, repairing and refurbishing their products. These services are provided personally and professionally with emphasis on outstanding quality in all the interactions with customers. This further supports the life long company-customer relationship. Although not a requirement for dealing with Vitsœ, its website enables customers to keep records of all their planning drawings and allows them to follow the process of their order. The website also provides clear information on selecting, designing and installing its shelving systems.

4.3.3 The development activities

Although Vitsœ is design based and Dieter Rams still works with the company, very few activities revolve around new product design. Following their ethos the objective is not to develop products that attempt to satisfy ever changing market demands, but rather to create products that will last as long as possible. The business is based on the existing products in the company. Vitsœ's development strategy is focused on customer service and supporting long lasting individual customer relationships, as well as optimising its value chain in cooperation with suppliers. No formalised development procedure exists in the organisation but '*design thinking*' is embedded in the company's culture. Planners and installers are expected to understand customer needs and propose solutions to customer problems. Being a small company, the managing director, Mark Adams, is heavily involved in all the major development projects and helps ensure that they are effectively implemented with integrity and coherence.

Vitsœ has redesigned and developed the product life systems surrounding their products. Some examples are:

- Wooden stillages were specifically made to handle high value aluminium parts. Together with cardboard packaging they are kept in a closed loop, returning to suppliers in the otherwise empty trucks to be reused.
- Installers transport the wooden cabinets in specially designed tautliner canvas bags instead of cardboard which are constantly reused (see Figure 4.9). All cardboard packaging is also returned and if possible reused so that no waste is left at the customer's site.

- Installation tools (incl. a dedicated spirit level) are provided in a cotton bag to the customers that wish to install the shelving systems themselves. Vitsœ registers which customers have already received the tools, so that they do not resend the same tools to customers that already have them.
- A web-based product life cycle information system manages the complete process from initial customer inquiries, orders, logistics, production jobs, installation, accounts, and follow up. The system also registers details of customer interactions and photos of the customer's site to help planners and installers serve the customer effectively.

Vitsœ sometimes works with interior designers and architects on projects, but tends to prefer having direct contact with the end-customer to best support long-term relationships.



Figure 4.9 To transport its wooden cabinets (left) Vitsœ uses specially designed tautliner bags (middle) which it reuses (right) saving on packaging and reducing environmental impact.

4.3.4 PSS implications

Vitsœ is interested in leveraging its existing customers' experience of its products and service capabilities to new customers. One of the feedback items often received from customers is: *"I wish I had done this sooner."* Although Vitsœ's current business is based on the sale of products, the company already has service and life cycle thinking competencies in the organisation that are essential for PSS. The managing director is actively considering *"not selling furniture but allowing you to buy its use"* and become responsible for keeping the product cycle closed (Adams 2007).

4.4 Case study D: RiverSimple

RiverSimple is an entrepreneurial company that aims to develop a platform for the development and commercialisation of highly fuel efficient hydrogen cars in order to reduce the environmental impact of personal mobility (www.riversimple.com). The cars are developed in collaboration with research teams at Cranfield University and Oxford University as well as government and industry partners (e.g. environmental protection agency, hydrogen suppliers) and component suppliers (e.g. fuel cells, composite materials, etc.). RiverSimple is based in the UK and founded by Hugo Spowers, an engineer and former

racing car driver. Currently the company is working on functional demonstrator cars, and plans to launch commercial production by 2013.

This fourth case study on RiverSimple is similar to the third case study with Vitsø. The same PSS concept design methodology was employed but this time with a small entrepreneurial technology company. The company is currently developing hydrogen powered cars in collaboration with university research teams. At the time of the study RiverSimple's development activities were focused on the technical development of the cars, but acknowledged that in order to succeed the introduction of the car to the market required a business model and delivery system that was very different to what existed. Over a period of two months, four development meetings were held with three different company informants. The author followed the structure of the proposed PSS design methodology to lead the company from identification of PSS opportunities to six PSS concepts. Again in the role as an action researcher, the author performed most of the development work and gathered notes during each interaction with the company. A semi-structured interview was conducted with the company founder and project manager at the end of the project. Both this case and the Vitsø case study represent the prescriptive study in this PhD project, where a methodology for PSS conceptualisation was applied in a company context.

4.4.1 The business

Although a very small company in the highly structured and competitive automotive industry RiverSimple sees an opportunity to totally redesign the car to suit fuel cell technology. The automotive industry has optimised cars and processes in relation to combustion engines and has only attempted to substitute the engine with fuel cells instead of redesigning the whole car. Initial studies show that a completely redesigned hydrogen car could offer a personal driving experience at competitive costs and reduce the environmental impacts. Being a new entrant on the market with a new technology, and constrained by relatively high cost of fuel cells, RiverSimple knew that it had to rethink its whole business model including the supply and distribution chain. One thing that RiverSimple made clear from the start was that their cars will never be sold – only leased. RiverSimple's business model stands in stark contrast to the dominant strategy in the automotive industry which is to sell as many cars as possible without providing the fuel. Instead of attempting to sell as many cars as possible, RiverSimple aims to offer its cars based on their availability and use with costs for fuel and maintenance included (i.e. the customer pays per mile driven). The company is thereby motivated to ensure that the car is cheap to operate, reliable and long lasting.

The market for 'green' cars has an enormous potential. Climate change and rising oil prices have created global demand for cars with low carbon emissions. Although the automobile industry has been very successful in optimising car design and manufacturing based on combustion engines, the huge investments made in production and distribution as well as die-hard consumer habits and behaviour has resulted in an industry reluctant to radical change.

RiverSimple is also encouraging their suppliers to not sell them components but lease them (through Limited Liability Partnerships). This would support the shared responsibility in the collaborative effort of developing a totally new car, but would also give incentives for providing long-lasting components and possibly also help close the material loops. Another dimension RiverSimple was considering in its development of the car is to allow *open source development*, where information and specifications of the design are made publicly accessible. This was thought of as a method to rapidly advance the development and optimisation of the various car systems.

4.4.2 The products and services

Two functional concept cars are currently being developed: LIFECar, a hydrogen fuel cell sports car developed with the Morgan Car Company, Linde and QinetiQ; and Hyrban, a lightweight city car (see Figure 4.10). This case focuses on the Hyrban which is a two door, two-seater city car weighing just 350 kg, powered by a 6 kW fuel cell and four in-wheel electric motors that will get it to at least 50 mph and accelerate in 5.5 seconds. Its range is expected to be 320 km (200 miles).



Figure 4.10 RiverSimple's two-seater Hyrban (Hydrogen Urban Vehicle).

Fuel cells are relatively more expensive than conventional combustion engines, but with electric motors and ultra-capacitors can deliver the

same performance with less power than an equivalent combustion engine. Feasibility is furthermore achieved by severely reducing the weight of the car. (i.e. using carbon fibre (which is also well suited for small series production), limiting it to two seats, and eliminating accessories by offering 'luxurious simplicity/minimalism').

The Hyrban will only be offered as a lease with full maintenance and fuel costs included, consistent with RiverSimple's strategy. The details of this as well as the life phase systems (or infrastructure) needed to provide this were not fully determined at the time of the study.

4.4.3 The development activities

The company's development activities are currently technically focused on demonstrating that they can build functional concept cars. This is done in collaboration with suppliers of various components and university research teams. At the time not much effort had gone into developing a strategy for introducing the cars to the market and other customer-oriented aspects of the business. However, RiverSimple had formulated a clear strategy to its design and development. The company was applying a whole *system approach* where alternatives of subsystems were evaluated at the overall system level, and not just sub-optimised. As RiverSimple cannot leverage upon being a large manufacturing company with many resources, it relies on its flexibility and the novelty of the technology to collaborate with others in development. RiverSimple's design approach is built upon five key pillars (Spowers 2006):

1. ***Network hybrid platform*** – all powertrain components are connected to each other in a way that allows energy to be captured by ultra-capacitors when braking, and then provide most of the power when accelerating again. As the fuel cell only needs to be dimensioned to maintain the top speed (and not provide all of the acceleration) a smaller and lighter fuel cell can be used.
2. ***Open source collaborative design*** – the design of the vehicle will be publicly available, so that individuals and organisations can use and improve them with their own ideas. This is expected to keep development costs and risks down whilst increasing quality, efficiency and ultimately adoption.
3. ***Sale of service model*** – as the Hyrban will only be provided as a service with use, fuel and maintenance costs bundled together, RiverSimple will be incentivised to constantly reduce maintenance costs as well as increase reliability, product life and energy efficiency.
4. ***Distributed manufacturing*** – instead of centralised mass production plants, the production of the Hyrban will be distributed in smaller units geographically close to where they are provided and used. The structural body of the Hyrban will

be made of advanced lightweight composite materials, which do not require large manufacturing facilities.

5. **Multi-stakeholder governance** –it is not just the vehicle itself that is considered from a whole system approach but the common interest of all the stakeholders, e.g. hydrogen suppliers, retailers, service providers, customers, etc. are considered. This is expected to generate greater goodwill amongst all.

It is evident from this that the Hyrban's design and product characteristics are well-suited to match how the car will be developed and produced, and this in turn fits well with the service business model it will be sold under (see Figure 4.11). By taking a whole systems approach RiverSimple has been able to coherently align the product, the services and the business model so that they are each mutually supportive of each other.

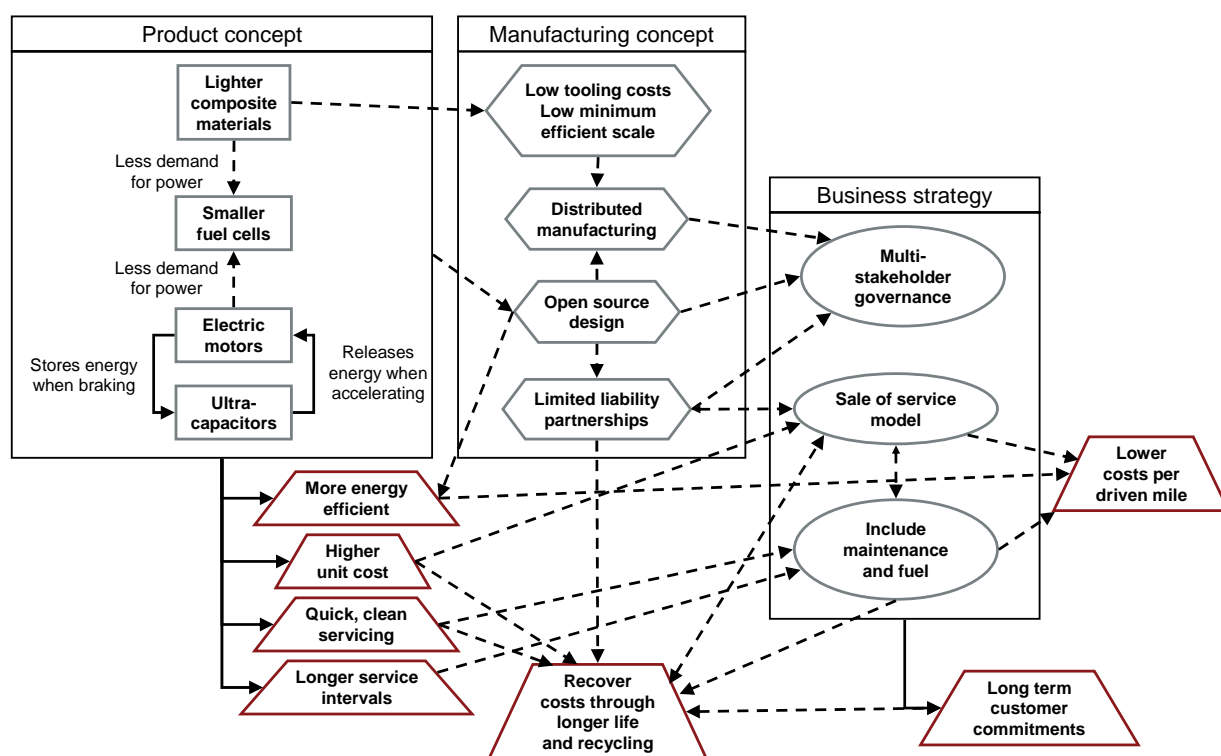


Figure 4.11 A visualisation of how characteristics of the Hyrban product concept is related and aligned with the development, manufacturing and business strategy (after Hugo Spowers).

4.4.4 PSS implications

RiverSimple is an example of a company that is applying a PSS approach, with services as an essential part of the business model, from the very beginning. As an entrepreneurial company it is not bounded by already existing product-oriented systems and culture, but can re-design the entire product and providing system to be well suited for PSS

approaches. However, since RiverSimple's cars and supporting systems are still in development, this approach has yet to prove itself on the market as there are still a great number of barriers to be overcome.

4.5 Case study E: SCA Hygiene Products

The fifth case study describes the integrated products and services of SCA Hygiene Products, a large global manufacturer of paper-based incontinence products (i.e. diapers and pads) as well as the structuring of its development activities. The company's customers are mainly public healthcare institutions. This case study investigated how the company was focused on supporting its customers by optimising the use of their products and reducing their consumption. Although the company is successful in delivering PSS, SCA was searching for ideas and techniques to collaborate more closely with its customers when developing new product and service delivery contracts. Information collection in this case study was done by interviewing (semi-structured) key informants in the company and its customer's organisation. In addition, the author made observations during a customer meeting (at the customer's facility) and organised two workshops (on actor networks): one internally in the company and one in collaboration with a customer. Public and company internal documents were also accessed and complemented other information found on the Internet about the company and its offerings. All interviews and workshops were completed in a period of three months (November 2008 – January 2009). This case allowed the researcher to apply the conceptual framework to describe the company from a PSS perspective and apply parts of the PSS design methodology in a company that already offers PSS. Thus this case study provided evidence for both the prescriptive study and the second descriptive study.

SCA (Svenska Cellulosa Aktiebolaget) is a global Swedish corporation that develops, produces, markets and sells pulp and paper-based personal care products, tissue, packaging, publication papers and solid wood products (www.sca.com). As a corporation it employs approximately 50,000 people in more than 90 countries covering four business areas: Personal Care, Tissue, Packaging and Forest Products (SCA 2007a). In its business area of Personal Care, SCA is the world leader of incontinence products which together with a broad range of related services are sold under the TENA brand (www.tena.com).

SCA started in 1929 as a forestry, sawmill, and pulp company. In 1975 SCA acquired Mölnlycke, a manufacturer of pulp and paper-based hygiene products which amongst other things also produced disposable diapers (nappies). This represented the first step to becoming a consumer goods company. This case study is about the Health (i.e. incontinence) Care division of the Danish subsidiary, SCA Hygiene Products A/S and one of their customers Lyngby-Taarbæk Kommune (a

large municipality just north of Copenhagen). With its services SCA Hygiene Products A/S attempts to ensure that its products are used optimally, so that care institutions (e.g. nursing homes) can achieve time and money savings, better work conditions for their care providing employees and well-being for those with incontinence. SCA Hygiene Products is based in Allerød (25km north of Copenhagen) with about 100 employees. For more about this case see the report (Tan & McAloone 2009).

4.5.1 The business

In Denmark the majority of incontinence products are sold directly to public sector institutions, i.e. municipalities and hospitals, as the Danish public health care system provides incontinence supplies to anyone that is diagnosed with incontinence. The annual public expenses for incontinence products in Denmark are estimated to be 200 to 300 million Danish kroner. A small amount of products are however also sold directly to consumers through retailers.

Incontinence (bladder/bowel weakness) is a common condition that affects 5 – 7% of the world's population (SCA 2007a). In Denmark alone approx. 400,000 people live with incontinence daily. Incontinence can affect everybody but the prevalence increases with age. Between 70 to 80% of all residents in nursing homes are incontinent (Brodersen 2003). In spite of the great prevalence, incontinence is generally tabooed which means that few people seek help on their condition even though it can be cured or at least relieved with incontinence products. The market for incontinence products is expected to grow with ageing populations in society. Globally SCA has by far the largest market share of incontinence products (26%) (SCA 2007a). In Denmark SCA has approximately half of the market with only one other major player actively present.

According to EU legislation the purchase of goods and services over a certain amount in the public sector is subject to the rules of public procurement and procurement contracts must be open for bids every four years. This means that most of the incontinence products in Denmark are sold through public tender contracts. The tender process is managed by public procurement officers and the directors of elder care in the municipalities. The tender is made public and suppliers are invited to give offers. Previously only tenders for incontinence products were described in the tender documents but today training and other services that support incontinence care are specified. It varies how the municipalities describe their tender, as integrated product and service bundles, or as separated products and services. Through the restructuring and merging of municipalities in Denmark, the procurement functions have become more centralised and professional. The tender contracts have also increased in size. Typically a user group consisting of continence nurses are associated to the tender process to

assist in the specification of the quality of the products and to determine how the different criteria in the bid should be weighted. The public procurement process puts forth a great demand on all suppliers to document the added value of their products and services.

The corporate strategy at SCA was at the time of the study based on value-added products and increased sales in emerging markets (i.e. Eastern Europe, South America and Asia). The global demand for disposable hygiene products is growing with increased affluence. SCA leads in the incontinence product market, where its strengths are customer and consumer (user) insights; its regional presence with global skills; efficient production; and a strong focus on sustainable development. SCA's products may not be the cheapest on the market, but due to its high quality and value-added benefits, they are cost effective when taking into consideration the total costs of incontinence care. Therefore SCA takes a holistic view on incontinence care which considers the well-being of the individual person with incontinence, the work conditions for the care giving personnel, and the total costs of incontinence care in the municipality. Incontinence products account for only about 1% of the costs in a nursing home, but studies have shown that when the time used on incontinence care is included, this amounts up to 13% of the all operating costs (Brodersen 2003).

The public sector in Denmark faces great challenges today with an increasing number of elderly requiring care. Nursing institutions are experiencing increasing costs and decreasing resources per resident as well as difficulties to find, train and retain skilled staff. Incontinence care is not just limited to the use of pads and suppliers, but includes a complex organisation of individuals with incontinence, doctors, continence nurses, care giving personnel, nursing home managers, procurement officers, municipality officials, family members, etc. (see Figure 4.12). All of these actors play a role in ensuring optimal care, which makes the management of incontinence care an intricate task. SCA attempts to reach out and support all levels of incontinence care and therefore has to deal with multiple actors which each represent the 'customer.'

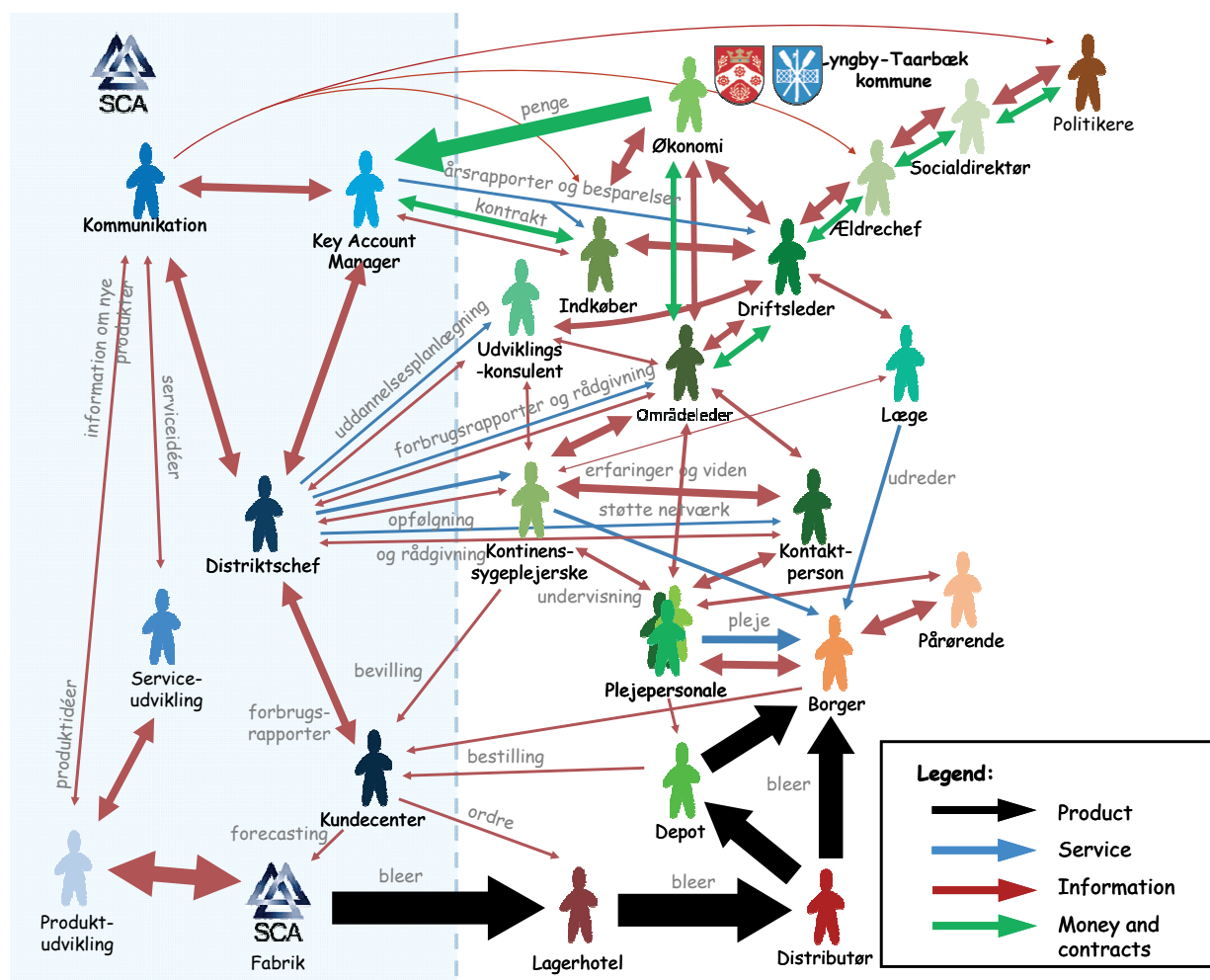


Figure 4.12 The actor network that provides incontinence care in Lyngby-Taarbæk Kommune (Municipality). SCA has to manage relations to the municipality's organisation on many different levels in order to achieve the benefits of its value proposition.

4.5.2 The products and services

SCA's range of incontinence products covers disposable pads, protective underwear, fixture pants, underpads, wash cloths and wash creams (see Figure 4.13). All the products are designed with particularly user comfort, ergonomics and leakage protection in mind. Environmental concerns are also prioritised highly, but rather than only consider the individual pad, SCA believes in providing the best functionality and thereby reducing the overall consumption of pads per user. SCA owns and manages large forest areas and plants many more new trees than it cuts down. This means that its forests absorb about the same amount of carbon dioxide as the total emissions to the atmosphere from all of its production facilities (SCA 2007b).



Figure 4.13 Some of SCA's incontinence care products including pads, support pants, underpads, wash cloths and wash creams.

SCA's pads consist of an absorbent core, which is a mix of fluff pulp (cellulose fibres made from wood) and super absorbent polymer (SAP); a permeable non-woven layer; and a polyethylene film which acts as a breathable barrier layer. During the life cycle of a pad, the greatest environmental effects occur during the extraction of raw materials and production, mainly from the production of oil, polymer and pulp, but if the pad leaks, this induces washing of clothes and bed sheets, which severely adds to the inconvenience, costs and environmental impacts. To ensure that this is minimised, SCA offers a full range of services that aim to help nursing institutions and care providers reduce the need for pad changes and minimise the consumption of pads per person with incontinence (see Figure 4.14).



Figure 4.14 SCA's full range of incontinence care services that are aimed at helping nursing institutions to provide the best possible care while optimising the use of resources.

SCA's TENA services are structured on a three step process:

1. **Plan** – An assessment of the current needs and potential for improvement for incontinence care in the municipality and its care providing institutions. Objectives are formulated and an action and implementation plan on how these can be achieved.
2. **Coach** – Education courses, training and support of care giving staff to ensure that the incontinence products are used correctly and optimally. An individual ordering and distribution system is set up which allows SCA to track the consumption of each individual user with incontinence. Access to specially trained incontinence care nurses and the facilitation of a network to develop incontinence care competencies.

3. **Monitor** – Regular visits are made at each nursing institution to follow-up on the achievement of objectives and management of consumption together with consulting and guidance on how to continuously improve on the performance of costs and care.

Although it would seem counterintuitive for a business based on the sale of products (the cost of the services are bundled with the product), the combination of these products and services are key to SCA's success among nursing institutions. The contracts for incontinence products are rather large and as they are regularly evaluated SCA has to always ensure that its market offer is competitive.

4.5.3 The development activities

The global product and service development functions in SCA Hygiene Products are centralised in Gothenburg, Sweden. Even though services are an important part of SCA's value proposition, the greatest amount of resources is used on the development of products. About 100 people are employed with product development, whereas the global service development activities are only coordinated by a small team and managed by a service director. Their task is to develop a corporate approach to the company's service offerings and oversee the development of specific local services in each country or region. The market structure and customers vary according to country depending on the health care system. Each region has product and service managers that report back about market demands and new business ideas.

Global product development

Disposable pads are standardised consumer products that are manufactured in large quantities. The products and their production systems are optimised in relation to each other, which makes it costly to make changes to the design of the product. New products are only developed if the global market potential for them is sufficiently large enough. The development of new products is very user-focused which in particular means that product properties such as absorbency, comfort, ergonomics, leakage protection, skin-care, etc. are very important. Product development is conducted in cross-functional teams composed of R&D, design, marketing, production, etc. and follows a stage-gate model. The past years the service team has also been involved in the development process. Furthermore, the organisation has an internal "idea suggestion box" that allows employees from any part of the company to send in product ideas and improvements. These ideas are collected centrally and evaluated in relation to their economical and technical feasibility and potential.

Service development

Service offerings, such as direct (home) delivery, training and consulting, have always been provided by SCA but it is only in the past 8 years that these services have been structured and clearly communicated to customers. Service development in the company actually only became a focus after a new type of incontinence products was launched on the market (TENA Pants and TENA Flex). These pads were a radical improvement for the user and were also used in a different way compared to traditional pads, but they were also priced higher (Cederqvist et al. 2002). The higher price could however be justified from a total cost perspective that also included the reduction of leakages and pad changes, but this was not always apparent to customers. SCA had to therefore document this value perspective to its customers and create a different kind of sales material. In this case the value proposition of these new products shifted from not just the product's user-centred properties, but had to include all the consequence costs related to incontinence care. It was rather this realisation the company made, that although it had developed innovative and improved products, it was crucial to develop the customers' (i.e. care providing personnel, nursing institution managers, etc.) - and not just the end users' - value perception. This led to a customer-focus and service-orientation that supported the customers and their activities. Centrally in SCA a corporate and international perspective was taken and all existing service and training packages for the institutional market in all the countries were examined, and then subsequently standardised and made more efficient. The idea was not to 'invent' new services, but build upon the services that already existed and worked well. These services were then communicated more clearly internally and externally in the organisation. The services were launched as TENA Services, a platform of services (Plan, Coach and Monitor) that supported nursing institutions in their incontinence care. Services allowed SCA to then offer value propositions on three levels:

- *Incontinence products* (i.e. pads, etc.)
- *Incontinence care* (i.e. education, training and guidance to care giving personnel)
- *Incontinence management* (i.e. cost, care control, supervision of consumption, planning and total cost counselling to nursing institution managers)

Today SCA has a service development team based together with the global product development function in Gothenburg, but in size and resources it is much smaller in comparison. The development task for services are also different compared to products:

- Product development is very focused on the consumer (user with incontinence) whereas *service development is aimed at customers* (those that buy incontinence pads and help people

with incontinence, i.e. care giving staff and nursing institution managers).

- *More focus on the early phases* of service development where the customer's value perception, activities and needs are studied. For example instead of developing another pad, service development investigates the staffing issues at a nursing home.
- *The development of services also occurs locally* in the individual countries and regions. A part of the task for a centralised service development team is to support these local initiatives and assist them to be better to develop new local services as well as make the locally developed services visible to the rest of the organisation, so that they can be inspired and build upon them.
- The result of *service development is rather a platform* on which service offers can be customised to the individual customer. A service launch process follows service development where both market communication and distribution is planned. Then there is also a local service launch process where the local service providing organisation has to identify which people needs to be involved, trained and which customers should be the first to try the new service. Each country has different local conditions, particularly with the financing and distribution system that determine how new services can be delivered.

The service development in SCA is still evolving. Despite discussions about the importance of services for the business, the company is still very product-oriented. The thought of greater service-orientation is not well grounded in top management, but there are many in the organisation that believe this is the way forward.

4.5.4 PSS implications

Value-added products and control of the delivery system in this case seem to be the main prerequisites for SCA to become a strategic partner. Even though SCA's business is based on the sale of products, it actively engages in how its products perform with its customers. It is very involved in how its nursing institution customers use and consume its products. The company has a very strong customer and service-orientation which aims at supporting its customers to use its products optimally in relation to care for those with incontinence, ergonomic and efficient work routines for the care giving staff and overall economic savings for the nursing institutions. This approach is characteristic of PSS approaches where companies take greater responsibility and an active role in the use of their products to benefit everybody economically, socially and environmentally. In this way SCA shows that it is possible to offer high quality products that are more expensive than others on the market, but when considering the total system, it is very cost-effective and the least environmentally harmful choice for customers.

An important aspect of SCA's value proposition is that its total product and service offer is directed at multiple levels in its customer's organisation which makes them a strong partner in incontinence care. But in order to maintain the support of its products, it must constantly follow-up and actively engage all levels of both SCA's and the municipality's organisation. The development of products and services has to be systematically integrated and continuously upheld to enforce their value proposition. With SCA, it is the strong customer and user insight which together with the life cycle focus on its product that are the main components of PSS development.

4.6 Summary

In this chapter five case studies that provided insight to PSS in practice were briefly presented. A broad introduction to each case was given to set the context, background and relation to PSS development of each case study. In the following chapters, these case studies are analysed and investigated more in detail when attempting to answer the research questions formulated in Chapter 1.

- Case study A, the *PSS design course* for engineering students gave an idea of how PSS design can be structured as well as determining the essential elements of PSS concepts through product life phase systems, the activities of actors and the actor network.
- The second case study on *Steelcase* provided deep insight to the product, service and business development activities in a large global organisation and how they were related to each other. This is helpful for understanding how PSS may be developed in the context of manufacturing firms and their existing business.
- The third and fourth case study (*Vitsø and RiverSimple*) both represent attempts at applying a PSS design methodology in a company context. Although both cases described small non-traditional manufacturing companies this allowed the author to experience how PSS development is related to the entire organisation and the companies' business strategy.
- The last case study with *SCA Hygiene Products* was more a descriptive study of how the company's PSS was developed, delivered and maintained together with its customer. The objective of this case study was to bring together the research and findings from the other case studies and apply them in another context than what was first studied.

5 Understanding the synthesis of PSS

The aim of this chapter is to address the first research question, by establishing a theoretical foundation for the synthesis of PSS. In Chapter 2 the literature and various perspectives of design were studied in relation to products, services and PSS. Based on this a theoretical framework for the synthesis of PSS is formulated in this chapter. The framework builds upon the tradition of systematic approaches and structuring in Engineering Design and incorporates the design of services. The intent is to propose a framework that supports the systematic development of PSS and endorses the potential of integrating products and services.

An on-going endeavour in Design Science is to understand the synthesis process of design. Several researchers have already formulated theories about products' structural and behavioural aspects as well as the relations between these attributes (Suh 1990; Hubka & Eder 1996; Pahl & Beitz 1996). But in relation to PSS, it appears that no corresponding theories have crystallised about the structural and behavioural attributes of PSS. At present no mindset for the conceptualisation of PSS - based upon the nature of service in design and its interaction with products, users, and the user's or customer's activities - has been formulated. This is not only an academic challenge but also relates to industrial work practice when manufacturing firms wish to expand their business to also include services. If a manufacturer wants to exploit the innovation power and environmental potential of PSS approaches, it is also dependant on the ability to identify causes and the origination of effects of products throughout their life.

This chapter starts by contemplating, *what are the conceptual elements of the object of PSS design?* Hubka's Transformation Model (Hubka & Eder 1988), a dominant model used in the synthesis of products, serves as the point of reference. Based on the importance of three PSS perspectives, modelling techniques that support the conceptual design of PSS are presented. Next the development activities of PSS design are considered. PSS development is compared with Integrated Product Development (Andreasen & Hein 2000) to determine how it is different from product development. PSS is also seen as an integrative strategy that links the value creating activities in a manufacturing company. Here a reference model for PSS development is proposed.

5.1 Formulating theoretical frameworks

Theories and models in research are used to explain observed empirical phenomena. As has been presented in Chapter 2, Design Research has a set of models and theories that have been beneficial for understanding

the design of (physical and technical) products. The objective of this thesis is to begin the same task for the design of PSS. A theoretical framework is a type of intermediate theory that generically structures constructs that can be observed in real life and relates them to each other. Theoretical frameworks act as an overview or map to coherently describe and communicate the theoretical elements and principles of a research object. In this thesis the established theoretical framework in Engineering Design is applied to PSS.

There are several motives for proposing new theoretical frameworks for the design aspects of PSS:

- to bridge the knowledge in systematic approaches in Engineering Design with the emerging knowledge of service-oriented approaches;
- to pragmatically structure the insights of PSS development for pedagogic and practical purposes to teach students and inform industrial practitioners on how to effectively design and develop sustainable PSS; and,
- to support the coordination of development activities in manufacturing firms by visualising the needs of integration across the organisation.

As described in Chapter 3, the approach used to formulate the theoretical framework in this thesis is by identifying the essential elements of PSS and then classifying and correlating them to each other (Carlile & Christensen 2005). This chapter brings together the theoretical insights achieved, whilst Chapter 6 and 7 confront the framework with empirical case studies.

	Products	Services
Design object	Physical artefact	Activity
Conceptualisation	Functions Structure, shape, dimensions, material, surface	Process Personnel, relations, information, procedures, products, physical environment, culture
Realisation	Production	Service operations
Design modelling	Sketches, (standardised) drawings, physical models, CAD models	Blueprinting, storyboards, experience prototyping
Design methods	Established methods	Emerging methods
Computer aids	Common practice	Under development

Table 5.1 A comparison of characteristics of product and service design methodologies based on the literature review using Buur's (1990).approach to comparing the main methodological characteristics of mechanical, electronical and software design.

Building upon the theoretical framework from Engineering Design, the first task is to determine what is the result or objective of the design and development activities in PSS approaches. In Engineering Design this

would be a product that is a physical technical artefact. Inspired by Buur (1990) the difference between methodological aspects of product and service design can be compared (see Table 5.1). The design object in services is an activity in which products, people and other resources are part of. A theoretical framework for PSS design should therefore be based on activities. An important condition for a good theoretical framework for PSS design is that it should take into consideration how it can support the development of design methods.

5.1.1 Design models

In particular the ability to model the design object is fundamental. Design models are used as abstract representations of design objects and allow designers to both: 1) *describe and communicate their structural characteristics*; and, 2) *to simulate, analyse and evaluate their behavioural properties before actual implementation* (Buur & Andreasen 1989; Roozenburg & Eekels 1995; Bitran & Pedrosa 1998). Models allow the behaviour of design objects to be studied at an early stage. They contribute to the understanding of design parameters and help indicate in which direction the preliminary design should develop.

Design models can be classified in two dimensions: *level of abstraction* and *level of detailing* (Buur & Andreasen 1989). The design process can be seen as a propagation of the design object from an abstract and undetailed model to a more concrete and detailed model (see Figure 5.1).

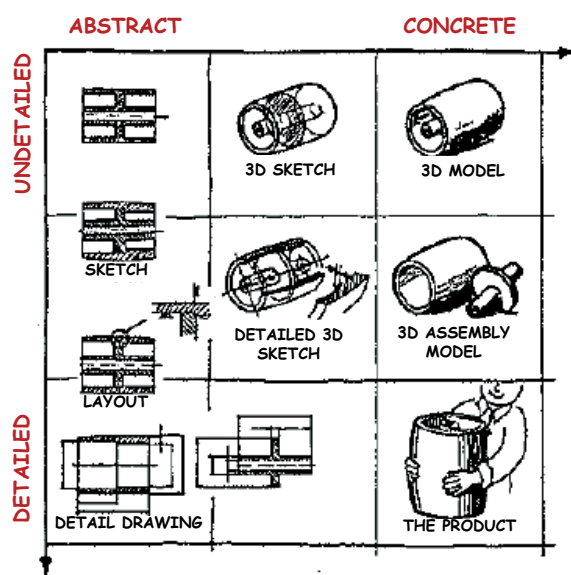


Figure 5.1 Examples of how design models are used from abstract and undetailed to concrete and detailed (Buur & Andreasen 1989).

From the literature on PSS in Chapter 2 and the PSS design course (Case study A) presented in the previous chapter, it was deemed that theoretical frameworks for PSS should naturally adhere to the following attributes of PSS approaches. These have been identified as:

- *Life cycle orientation* by considering both the production and consumption sides of products and services;
- *Customer and customer activity focus* because value and the fulfilment of needs can only really be understood by studying the actual use of products and services;
- *Systems thinking* by understanding complex systems composed of different elements from the perspective of the entire system;
- *Interdisciplinary* because PSS builds upon a wide range of different of knowledge areas and skills, e.g. technical, social, business, etc.;
- *Competitive business strategy* for companies of which design concepts must support; and,
- *Sustainability perspective* which includes the economic, social and environmental perspectives of products and services.

Now that the propositions of a theoretical framework for PSS design have been put forth the conceptual elements of a PSS design object is discussed.

5.2 The conceptual elements of a PSS design object

It was mentioned in the previous section that a theoretical framework for PSS design should be based on activities. In Engineering Design a well established model of transformation activities already exists: Hubka's Transformation Model (Hubka & Eder 1988) (see Chapter 2, section 2.4).

The product's use process and other activities associated with the product's life cycle have an essential importance when services are approached. The model of the transformation system (see Figure 5.2) shows the product's primary utilisation activities, where operators transform operands on the input side into something more desirable on the output side – all of these typically in the form of either material, energy and/or information. Here the focus is on the central use activity, but in actual fact all activities related to the product's life cycle should be taken into account, because they may influence and be influenced by the product's design (Olesen 1992). As follows from Hubka's model, the transformation system's performance is not only determined by the product, but also by the other operators and operands. As the product encounters different operators and operands throughout its life, the resulting effects of each 'meeting' is determined by how well the product, actor and life phase system perform together (Olesen et al. 1996).

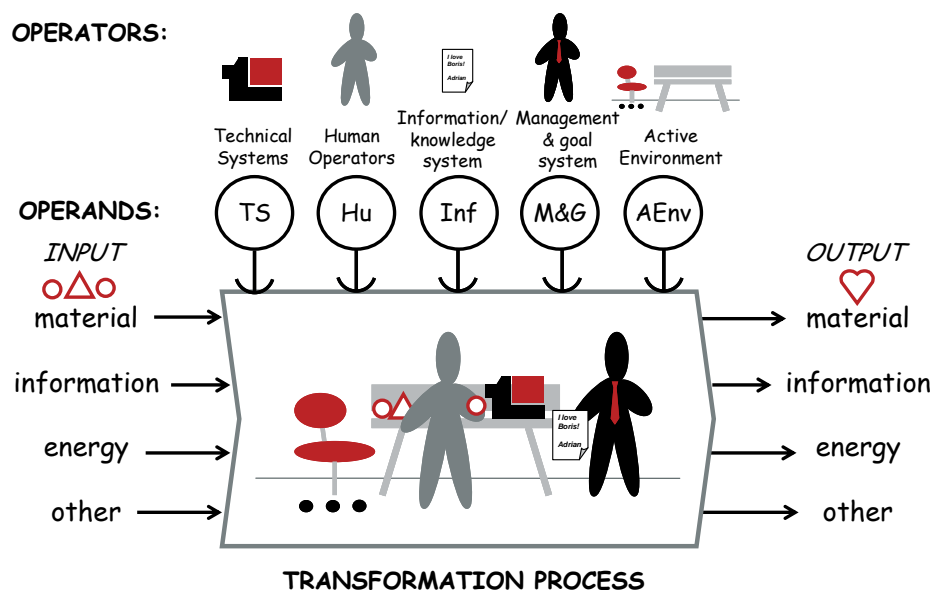


Figure 5.2 The use of a product (i.e. a technical system) in Hubka's Model of the Transformation System showing the operands and operators (after Hubka & Eder 1988).

Seen from a conceptualisation point of view the Transformation Model is an expansion of functional reasoning and a mode of action finding for conceptualisation. It helps us look beyond *what the product can do* to *what can be done with the product*. Understanding existing products' actual life cycle and use, or creating scenarios that capture the believed *raison d'être* of new products may be used for identifying proper roles, functionalities and qualities of a product, and thereby creating high (user perceived) value.

Services in the view of Hubka's Transformation Model do not change the intended transformation process but instead allow a company to – besides providing the product to the customer – provide any or all of the operators and/or operands of the transformation system. A company may for example choose to operate the product for the customer, deliver all necessary materials and energy, and take care of all by products, leaving the customer with just the beneficial results.

As the focus and intention in this thesis is the combination and utilisation of service-oriented thinking in companies that traditionally sell physical products, the product's service period, i.e. the period in which the product serves the user by being able to do what it is meant for, should be considered. Supporting, maintaining and ensuring this service may be enhanced, simplified, or ensured by adding services delivered from outside (seen in relation to users and their system). These services may be in the form of physical artefacts, manpower, activities performed, etc.

A PSS complies with the Theory of Technical Systems, i.e. it can be regarded as a transformation system with technical systems, operators, operands and the active environment. But as discussed in the literature

review in Chapter 2, this ‘service’ interpretation of the Transformation Model along the product’s life, does not lead us to all types of services. The customer’s activities also need to be included.

5.2.1 Two life cycles

The benefits of products and services derive from their properties, but the relational properties and quality are as much a consequence of the product life system and the customer’s activities as they are of the product. Traditionally the designer’s task was to improve the design of the product so it better suited the product life phase system and customer activities. With a service-oriented approach designers have the opportunity to also design the product life phase system and the customer’s activities. Designers still need to understand how the product, its life phase systems and customer activities interact with each other to ensure that the desired benefits are realised, but the means to achieve these are increased with PSS. Both the life phase system of products and the customer activity cycle perspectives can be seen as expansions to the traditional perception of the design object. To ensure that the desired benefits are achieved two fundamental life cycle systems must be considered and optimised in PSS (see Figure 5.3):

1. the *life cycle systems of the product*, representing a product-oriented view; and
2. the *activity cycle of the customer*, representing a service-oriented view.

This corresponds to the two typologies of product services given by Mathieu (Mathieu 2001a), ‘services supporting (supplier’s) products’ and ‘services supporting customer’s actions’.

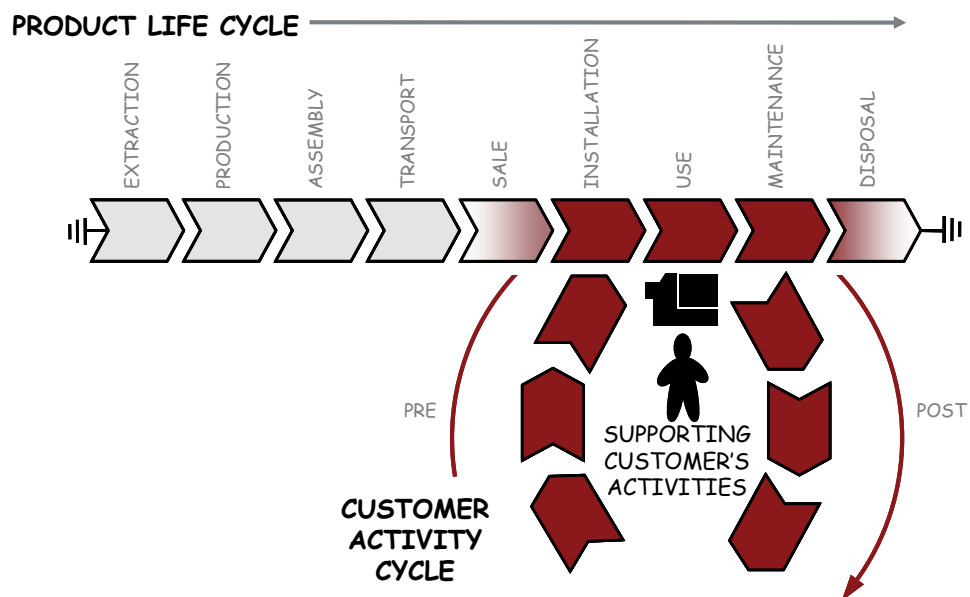


Figure 5.3 The two life cycle chains that need to be reconciled in PSS concepts.

Including customer activities into Hubka's Transformation Model results in a model that corresponds to Shostack's (1982) Service Blueprinting approach. This allows an integration of artefacts and activity types of services, but does not show the reasons or value relations for the customer's interest in these services. Vandermerwe's (2000) Customer Activity Cycle methodology helps here as it uses the customer's perspective as the point of reference, but this still does not explain how and why the human operators in the Transformation Model are motivated to deliver and uphold the value creating activity for the customer. For this it is necessary to consider who is responsible for the operators and operands during the transformation process.

5.2.2 Network perspective

As was seen in the literature in Chapter 2, products and services are rarely delivered by just one party, but often demand a network of actors to provide them. A network perspective allows designers to understand the motivations and incitements of the individual actors (Latour 1991; Donaldson et al. 2006; Vezzoli 2007). It can be disputed whether customer activities and networks can be seen as a design object in the same way as physical artefacts. Designers are able to fully specify a physical artefact by its structure, shape, dimensions, material and surface (Tjalve 1979), but they cannot fully determine the use of their products (Redström 2008). Like services, the use of a product is an activity. As customer activities and actor networks involve humans, they literally have '*a life of their own*'. Nonetheless, it is possible to influence these systems and orchestrate them to a certain degree that one may consider as *design* (Manzini et al. 2004). The perspectives of product life, customer activity and actor network can be understood in a similar way as the domains in Domain Theory (Andreasen 1992), but the relationship between the domains in PSS do not follow the Law of Vertical Causality where one domain determines the next (Andreasen 1980). The three dimensions of PSS are however causally related. A change in one dimension has an effect on another dimension. This allows design principles (general rules for the design activity that will frequently favour good solutions (Buur 1990)) in PSS to be formulated.

5.2.3 The fundamental dimensions of PSS design concepts

In the above the theoretical foundation in Engineering Design was expanded to include *product life systems*, *customer activities* and *actor networks* to be appropriate for PSS. The initial thoughts on how to describe a PSS in this manner were originally laid out by McAloone (2005) in his proposal for a normative approach to PSS design. These three perspectives are all interdependent and seem essential in the design of PSS if the intended benefits are to be realised. By combining these perspectives it appears that a good basis can be established for

understanding the interfaces and interactions in PSS. The perspectives embrace both the supply and demand side of products and services, as well as accentuate the value relations throughout the system. This would elucidate the business and environmental potential of PSS.

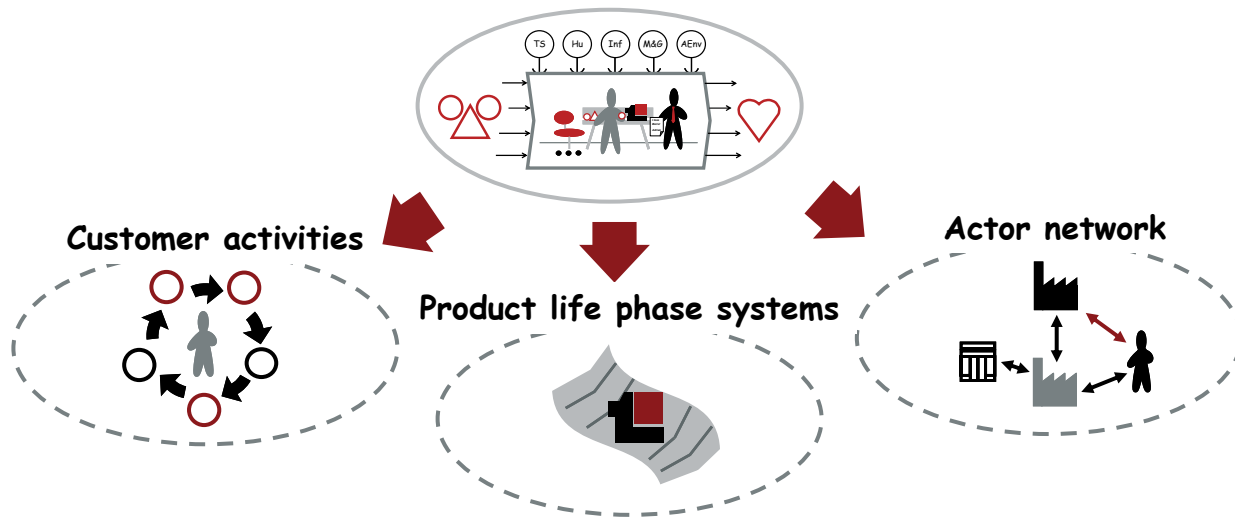


Figure 5.4 The three essential design object perspectives in PSS conceptualisation.

The product life phase system perspective allows designers to consider the design of the system the product becomes part of. The customer activity perspective allows designers to consider the chain of activities customers must go through and their behaviour in order to derive the benefits. The actor network perspective allows designers to consider all the actors involved in delivering the life phase systems and supporting the customer activities. The consolidation of these perspectives are expansions of the ‘product meeting’ in Olsen et al. (1996), where effects can be determined when a product, actor and product life system encounter each other. An interesting realisation is that the proposed PSS perspectives could be very useful in the traditional design of products as they support designers in understanding the context and system the product becomes a part of.

These three dimensions seem to grasp the fundamental aspects of PSS approaches. It allows designers to understand the economic and environmental impacts of the product throughout its life; the activities that customers engage with products to fulfil their needs; and how the many actors comes together to act as one system.

5.3 A model for PSS design concepts

This thesis postulates that services and products are bounded together by the user’s activities; that services are delivered or executed in a transformation system (Hubka & Eder 1988); and, that both products’ and services’ business aspects are based on value relations to the customer. Next to be investigated are the structural characteristics and behavioural properties of service systems that form this underlying

conceptual framework for PSS design. Here a theory of synthesis claims that the achievement of desired behavioural properties of a product (i.e. function, weight, cost, strength, etc.) can only be realised through the determination of structural characteristics (i.e. geometry/form, material, dimensions, surfaces, tolerances, etc.) (Hubka & Eder 1988). Within Engineering Design the structural characteristics have only been identified for physical artefacts and not for intangible services. It is therefore interesting to discuss the structural and behavioural attributes (i.e. characteristics and properties) of products and services.

5.3.1 Structural characteristics of PSS

Based upon the conceptual dimensions in the previous section the following insights concerning the nature of a PSS system may be given (Tan et al. 2008):

1. ***PSS has characteristics related to the product:*** From our scope of industrial change, the character of a PSS is linked to the manufacturing company's products. This thesis does not go into details with the structural characteristics of products as a theory about the fundamental set of characteristics of products (Theory of Technical Systems (Hubka & Eder 1988)) already exists.
2. ***PSS has service characteristics related to the transformation process:*** Services should support the transformation activity, i.e. the utilisation of the product. These characteristics may belong to any of the activities that are customer/user engages with the product. The characteristics may belong to any of the product's life phases: the distribution and sale, operation, the maintenance, or the disposal of the product.
3. ***PSS has characteristics related to the service channel or product life phase system:*** Services are channelled through the transformation process' operator system and infrastructure. The following types of channels can be imagined:
 - *Human systems (people).* The operators or actors are typically the primary means of delivering a service. Through direct participation and influence in the customer's activities, services that could belong to other channels, e.g. such as information or management, are provided by personnel.
 - *Technical systems.* This channel includes "the sold product" that determines the customer's activity process, e.g. a printing machine used in newspaper printing, but it could also be other technical products, such as auxiliary equipment (e.g. for cleaning, for packing newspapers, etc.)
 - *Information systems* that could provide the data about use, technical know-how, operational experience, layout support, production data, etc.
 - *Management and goal systems* that channel control, management, certification and deliver production plans.

- *Active environment and conditions*, e.g. in the form of space, work traditions, agreements, social status for operators, etc.
4. ***PSS has service characteristics related to the customer's activities:*** Service may be related to one or more steps in the activities, that are arranged by the customers/users themselves or that they get involved with before and after the utilisation of the product (the transformation activity). Besides service that is channelled through the operators in the transformation process, service providers can enhance activities with new or adjusted content that is connected to the customer's activity cycle, as e.g.:
- *Contracts* that ensure customers and/or their activities a certain level of risk or performance.
 - *Information* providing documentation or performance reports.
 - *Knowledge Consulting* services aimed to support the customer's objectives or performance.
 - *Financing* that provides the means to initiate and uphold the operators and/or supply of operands.
 - *Supplying auxiliary input* Continuing with the newspaper example, a delivery system for glue, printing ink, cleaning agents, etc., could be offered.
 - *Removal of by-products* This could be air filtering, wastewater purification, waste removal, etc.
5. ***PSS has characteristics that are related to the actor's network pattern and value enhancement:*** Delivering a service does not become a business relation unless the stakeholders experience benefits, here in particular the user and his or her activities. The enhancement of value can be based upon many types of quality enhancements related to the purchasing, installing, operating, maintenance, and disposal of a product.

It is difficult to capture these five PSS characteristics in one model or a set of interrelated models. Again it is surprising that most of the insight about these perspectives that ought to be established during the conceptualisation of PSS should actually also be present when conceptualising products on their own. The reason that this is not usually the case is that market and customer relations are managed by the sales/marketing organisation, and are generally not considered a major influence on the design of the product. This results in companies often following the mainstream or making risky guesswork about the use of their products and their customers. The conceptualisation of a PSS may take its starting point in any of the mentioned five characteristic groups or their sub-topics. It appears that close insight into the users' operation and problems, and their value perception is a basic condition for being able to design successful PSS.

5.3.2 Behavioural properties of PSS

A general trait of a man-made system is that structural design leads to certain behavioural properties when the product is established and in use, such as function, functional properties (performance dimensions), production properties, etc. However, users determine by their perception, preferences, experiences and value references, what they perceive as important properties of the system. Therefore, the designer is only partially able to create the value pattern and often the launch of a product on the market becomes a flaw because of a wrong interpretation of the users' wishes, attitudes and values.

Based upon the identification above of the structural characteristics and the composition of a PSS, a short and preliminary proposal is provided for PSS property classes, which can serve as an inspiration for identifying the important value relations between stakeholders:

1. ***The performance of the activities is related to the value proposition:*** In his thesis Olesen (1992) proposes seven classes of properties of an activity seen from the perspective of the stakeholder that is interested in the operation and the result of the activity: *cost, quality, time, efficiency, risk, flexibility, and environmental effects*. This set of classes differs from the traditional property classes related to products, as proposed for instance by Hubka (Hubka & Eder 1988) or Pahl & Beitz (1996). The activities related to a PSS may be both the product life activities and the activities related to the channels or product life phase systems. If the stakeholder perspective is changed from the owner or buyer to the actor in the service or product life activity, another set of values can be expected.
2. ***Actors experience PSS utility and value:*** Each of the actors has different experiences of utility and value. Many perspectives of value exist at the same time.
3. ***PSS ownership, availability and risk are the responsibilities of the provider:*** In terms of performance and usability, interwoven dimensions determine the availability and, in exceptional situations, breakdown and failures or absent deliveries. Seen from the provider's perspective the risk dimension is important, and several types of services are based upon risk minimising: systematic maintenance, operator training, insurance, etc.
4. ***The PSS is also a matter of soft qualities:*** Like consumer products, clothes and cars, PSS may also be related to soft qualities, which the buyer/user balances against the price, brand reputation, esteem qualities, product history, promotion, etc.

These four property classes overlap each other and are not a complete set of properties recognised by owners/buyers/users. However, the list can serve as an inspiration when the content of a value relation between

a supplier and a customer has to be judged: *Are the new properties attractive enough in the relationship to ensure that the total perceived benefits are greater than the total sacrifices?* If PSS as business models are to be successful in achieving better economic, social and environmental performance, this has to be clear in the value proposition.

5.4 PSS conceptualisation

As the product and transformation process is usually given for manufacturers, the three dimensions of PSS; *product life phase systems*; *customer activities*; and the *actor networks* seem to describe the conceptual design perspectives of a PSS. The behavioural properties of each dimension determine the effects of the entire system (see Figure 5.5). Similar to product life design, an analysis through these three dimensions appears to give a good understanding of how current products and systems 'work' and is also helpful in uncovering areas where the dimensions could be better aligned. A change in one of the PSS dimensions influences the others and the designer has to ensure that each of the dimensions of a new PSS concept support each other in order to be consistent. The potential for innovation and greater environmental improvement is related to what part of the system is considered and can be manipulated. The integration and coherence of the three perspectives is key to sustainability and what essentially makes PSS solutions feasible and competitive.

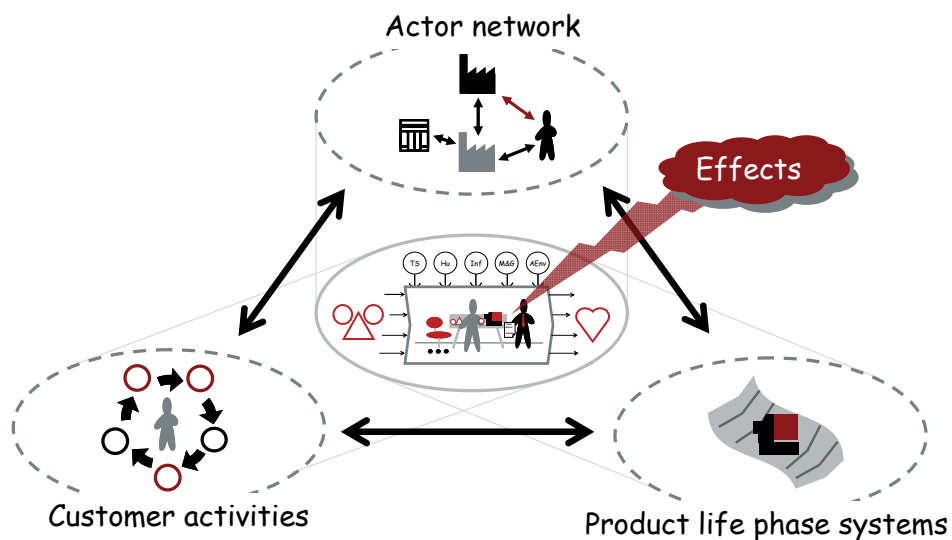


Figure 5.5 A meta-model for PSS conceptualisation that emphasises that the three dimensions of PSS concepts should be integrated and coherent to achieve the desired effects.

An integrated approach to these three dimensions can be achieved by considering the following causal relations and eliminating discrepancies:

- Matching the potential utility of products throughout their life with the benefits they provide in customer activities (i.e. matching production with consumption), e.g. by increasing the

performance of a product or making it easier to share the product, so fewer products are needed.

- Relating how the actors that are linked to each other through the product's life are incentivised to behave in a more sustainable manner (supply side), e.g. by paying back a deposit when products are returned to the manufacturer.
- Relating how the actors that are linked to each other through the customers' activities are incentivised to behave in a more sustainable manner (demand side), e.g. by not rewarding sales employees on the amount of product they sell.

The dimensions complement each other and allow designers to gain insight into both products and services in order to achieve the full potentials of PSS and to reap the environmental benefits of optimising the two life cycle systems. In practice not all dimensions are designable. Many of them are given within a company context. The proposed framework is thought of an awareness and mindset of potential or possible design degrees of freedom.

The conceptual elements of a PSS solution seem to be established when the technical systems, the activities, the channel/life-cycle systems and actor network are defined, coherent and mutually supportive. Both market/need and design/realisation perspectives are included in this model (Hansen & Andreasen 2003). The understanding for what needs to be and can be designed is expanded with PSS. This expansion of scope demands an intricate understanding of the relationships and interactions between artefacts and humans in so-called socio-technical systems (Bijker 1997), but at the same time provide a source for new innovative thinking.

It has not been possible to capture all these different characteristics in one perspective, so multiple perspectives are necessary to grasp PSS concepts. Although PSS approaches represent an expansion in the degrees of freedom in design, it is notable that these aspects should also be present in the conceptualisation of traditional products. Due to the way companies currently design and develop, manufacture, market and sell industry products, these "new" aspects of conceptualisation are often not considered systematically. The behavioural properties when designing cannot be determined directly, but emerge when the structural characteristics are confronted by different actors and their activities. In this sense designers will never be able to fully control the use of products and services. Only by insight into the user's or other actor's activities, problems and value perception can designers hope to achieve the desired properties of a product or service.

Conceptualisation of PSS may take its starting point in nearly any one or more of a PSS's attributes and elements, these are:

- the *value proposition* based on the activities the user and product is part of;
- the *service channel or product life phase systems* in which services are delivered;
- the *chain of activities of that customers* (or other actors) are active in extract product and service benefits; and
- the *network of actors and stakeholders* that mutually benefit from providing and receiving products and services.

When each of the dimensions are determined and coherent with each other, the entire PSS concept does seem to be well described and does form a comprehensive whole on which a basic understanding of the value propositions can be derived. It is interesting to see that when the above PSS dimensions are related to different areas of innovation as suggested by Tid, Bessant and Pavitt (2005), there seems to correspond well:

- *Product innovation* based on changes in the things (products or services) which an organisation offers
- *Process innovation* based on changes in the ways in which they are created and delivered
- *Position innovation* based on changes in the context in which the product or services are introduced
- *Paradigm innovation* based on changes in the underlying mental modes which frame what an organisation does

PSS seems to address all these possibilities for innovation. Typically product development would only cover product innovation, but PSS development includes the delivery system (a form of process innovation); service development is considered a mix of both product and process innovation; actor network (a form of position innovation); and, the change of value proposition (a form of paradigm innovation).

In the next chapter the case studies performed in this research project are analysed to provide empirical insight to the conceptualisation of PSS based on the dimensions presented here.

5.5 PSS design tools

So far three key dimensions of PSS concepts have been presented, but they have only been dealt with in abstract terms. The intention of this section is to present some of the concrete tools that can directly support the conceptual design of PSS. These tools have been borrowed from other fields but have been adapted to suit PSS conceptualisation as has been discussed in this chapter. All of the tools share a graphical approach to synthesising and analysing design relevant information (McKim 1980).

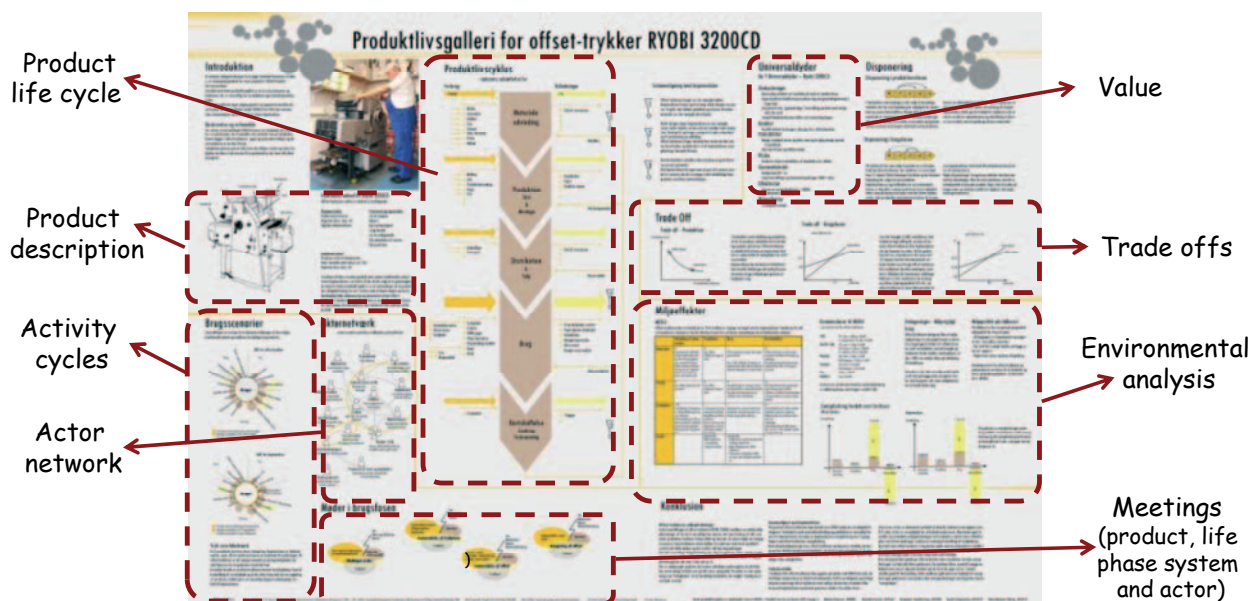


Figure 5.6 An example of a Product Life Gallery poster (real size A0) of an off-set printing machine with an overview of the reference product, its life phase systems, use scenarios, stakeholders, environmental impacts, etc. (student project 2007).

5.5.1 Product Life Gallery

The *Product Life Gallery* is a graphical overview of the product's life cycle and environmental profile (Olesen et al. 1996; McAloone 2007). It visualises the collective results of the qualitative and quantitative mapping of the product's life cycle, detailing the environmental effects, stakeholders, DfX impacts, trade-offs and dispositions (see Figure 5.6). Starting with an analysis of its physical components and materials the history and possible future life scenarios of the product is determined. By investigating the product's total life cycle, stakeholders, activities and life cycle systems (all traditionally not considered in product development) new opportunities are uncovered. Here the influences of each can be studied and the relationship between product and life phase be understood. Although originally focused on environmental effects, the Product Life Gallery is also well suit for all the other 'Universal Virtues' (i.e. cost, time, efficiency, risk, etc.) (Olesen 1992).

5.5.2 Customer Activity Cycle Modelling

A product's environmental effects are largely determined by how it is handled by the people interacting with it. The Customer Activity Cycle (CAC) methodology (Vandermerwe 2000) models the key stakeholders' needs and in the sequences of activities before, during and after interacting with the product or service. This mirrors the analysis done on the product life cycle and opposes the product and production oriented perspective with a service and consumption oriented perspective. The CAC's main virtue is the way it prompts the designer to consider the sequence of activities of the stakeholders, hereby contributing to the knowledge of the designed offering's use phase.

Here too stakeholders and activities otherwise not considered are uncovered. These represent potential for companies to influence or support the customer (or stakeholder) activities more effectively, as well as build stronger relationships.

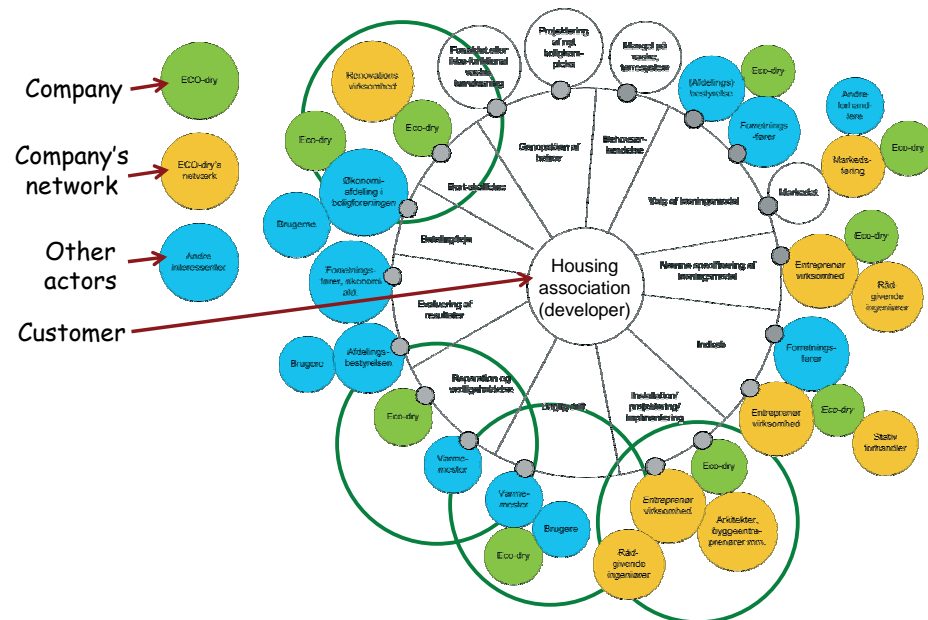


Figure 5.7 An example of a Customer Activity Cycle modelled over a housing association that introduces a new type of communal laundry facility showing which actors are involved in each activity (student project 2006).

5.5.3 Actor Network Modelling

For a system to be sustainable (in economic, social and environmental terms) the relationships between all the stakeholders have to be collectively beneficial. Through a mapping of active stakeholders as actors in a network around the product or service the flows of value, material, energy, information, service and transport are identified and contribute to a description of key issues in the network. Actor Network Theory (Latour, 1991) assists with considerations on how new products and services may be adopted and form an integral part of the socio-technical system. The actor network analysis brings attention to how shared understandings in the network produce entities which are implicit and taken for granted, but also how new tensions may evolve from the displacement processes that follow when the design objective is transformed from product performance to service system. An approach for visualising the actor network is here similar to Customer Value Chain Analysis (Donaldson, Ishii and Sheppard, 2006) which allows design teams to identify pertinent stakeholders and their relationships to the product or process being designed, but takes a broader view of the supply chain to include the multitude of the consumption and social system.

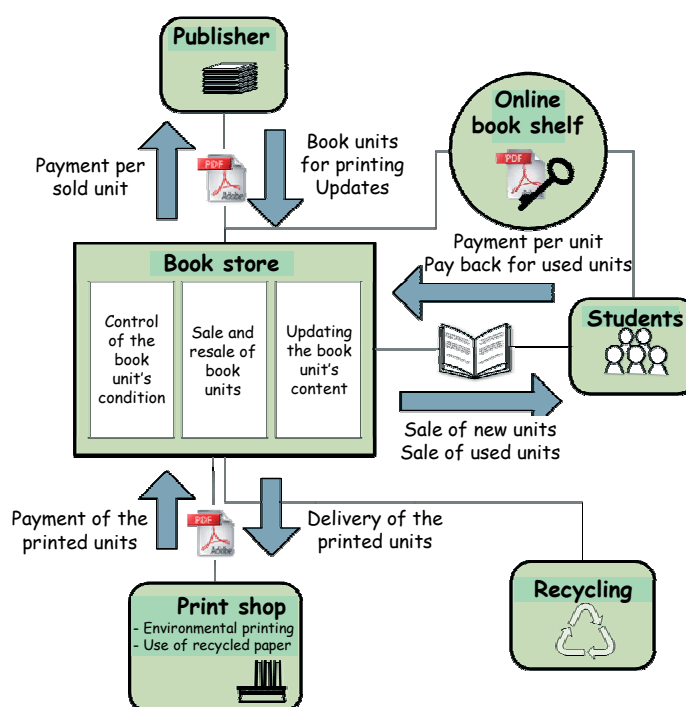


Figure 5.8 An example of an Actor Network modelled for a university book store that buys back text books, updates and resells them whilst giving students online access to the returned books (student project 2006).

The PSS design methods described above are all used in the case studies on PSS conceptualisation. These are presented in more detail in the next chapter

5.6 PSS development

Based on the model for understanding PSS as a design object in the previous section, the design process that leads to PSS is considered in the following. In traditional manufacturing companies the physical product is considered to be at the core of the offering (because it is assumed that the product carries the utility on its own) with services being complementary and supplemented in aftermarket activities. When developing PSS offerings, the tasks and abilities of the providing companies are expanded in new directions. With PSS approaches the customer's interaction with the product and its related activity is at the centre of attention. Value is created during the activity and based on the performance and outcome of the activity. This shift in view challenges the current understanding of development and the models used to represent the development task. In this section the implications of PSS and their relation to the development activities is explored. One way of understanding a company's development activities is by looking at its tasks and the system that performs them (Kirkegård 1988). In the following the development tasks related to PSS approaches are discussed. Then based on observations of the development activities in a global manufacturing firm, a generic model for PSS development is proposed.

5.6.1 Development tasks with PSS approaches

The general objective of product development activities is to provide the company the foundation for future business. Typically a company's development tasks can be identified on three levels representing strategic, tactical and operational activities in the organisation (Andreasen et al. 1989; TEKES 1999; Larsson 2007):

1. ***Business strategy*** that determines the overall operation and development of the company and how it establishes a competitive position on the market place.
2. ***Business/product planning*** that initiates and manages product development projects.
3. ***Product development*** that executes product development projects.

PSS approaches are innovation strategies that impact all three levels:

1. On the ***business strategy*** level, there is a shift of business based on the exchange of product ownership (i.e. product sales) to business based on supporting and enhancing the utility of the product through integrated products and services. This entails that the manufacturer must take greater responsibility for the life phases of its products after production and assume a new role as a service provider in the downstream market (Wise & Baumgartner 1999). Although manufacturers may have intimate knowledge of their products, they might not have the necessary competencies to operate as service providers. Here the manufacturer must develop new competencies and capabilities aimed at the customers' activities. If the manufacturer is not able to acquire or develop these capabilities within its own organisation, as is often the case, since services are typically provided locally, they will have to partner with other companies to provide the PSS (Sawhney et al. 2004). The main development tasks on the business strategy level relates to the formulation of strategy, developing core competencies and forming strategic partnerships.
2. On the ***business/product planning*** level the company has to also consider how services are developed and how they are related to other development projects. If the PSS requires multiple actors to provide the integrated products and services, it is not just internally in the organisation that business planning must be done, but in collaboration with the strategic partners. In some cases the customer is a strategic partner that is actively involved in the development of the PSS (Weber et al. 2004). It is on this level that PSS concepts are created.
3. On the ***development project*** level services are expected to be developed as systematically as products. If multiple actors are involved in providing the PSS, then their roles and responsibility

in the development projects need to be defined and managed. These development projects lead to the implementation of new PSS.

Furthermore with PSS approaches a dependency is created between the (providing) company's operations and the (receiving) customer's activities. Here the physical product is supported and enhanced throughout the customer's activities by the providing company. The business relationship with the customer may spread over several product upgrades and generations. This may be seen as an on-going customisation and development of the service and customer relationship, but also as an opportunity to gain valuable insight to customers and their activities. If systematically gathered and analysed, information about customers and their use of products could stimulate ideas and opportunities for new PSS.

Consequently PSS require a close integration of operations and activities operationally, tactically and strategically. A model for PSS development should therefore comprehend the integration across all these different levels of the company's development activities.

Since integration seems to be essential in the development of PSS, it seems appropriate to use Integrated Product Development (IPD) (Andreasen & Hein 2000) as a point of departure to consider PSS development. IPD is a broadly adopted model and can therefore serve as a strong foundation for a new framework. The strength of IPD as a reference model for companies is that it allows practical management and organisation of the development task. IPD models propose a certain manner in which companies may establish (Tan et al. 2006):

- the *development activities*;
- the *roles and responsibilities* of project team members and functional units;
- the *knowledge and competencies* involved; and,
- the *relationship of the development process* with other parallel corporate processes.

Traditionally manufacturing companies have not considered the customer's activities as a primary part of the value creation process, but merely as value extracting processes (Prahalad & Ramaswamy 2004). In product-oriented development models the process ends with a full product description or the realisation of production and sales. With PSS approaches the development task is expanded in time so that it also encompasses the use phase to ensure continuous development that is aligned with the customer's activities. In order to employ customers and external stakeholders as resources in the development process, the company must establish value co-creation activities in which they are encouraged to participate in (Cornet et al. 2001; Hippel 2005).

A key difference with the PSS approach to business creation, when compared to traditional product-oriented approaches, is that the manufacturer has the opportunity to play a greater role throughout their product's life period and not only in the production and sale of their products. For example, the manufacturer can take on the responsibility of their physical products during its use, maintenance and disposal phases and can thereby provide more value to the customer. Exactly how and to what extent this involvement throughout the products' life is, is a matter of how the value proposition is defined. Herein lies the possibility for companies to take upon the responsibility of the economic, social and environmental impacts of the whole life cycle of their own products.

The challenge for companies is to identify its '*opportunity parameters*' (Danish: 'handleparametre' from Andreassen et al. (1989)) in PSS approaches. Opportunity parameters are the degrees of freedom in design and development that can be exploited in order to create business value for one or more of the stakeholders involved (Matzen & Andreassen 2006). PSS approaches entail a certain set of opportunity parameters that manufacturers need to focus on to become successful with PSS. For example, if a product is not sold, but instead offered to customers based on the function provided, the opportunity parameters are that a more expensive (and technically advanced) product can be used to provide cheaper and more efficient operational performance (such as is the case with office photocopiers and aircraft engines). But for this to work successfully, the manufacturer might need to: integrate sensors and remote diagnostics into the product; ensure that equipment can be easily repair or components easily changed; develop software to track and analyse operational data; establish a network of service partners to offer preventive maintenance and repair; etc. All these aspects are parameters that can be employed to support the PSS. Business strategy formulation in this respect is about describing and integrating these different opportunity parameters and thoughtfully linking the relevant activities in the organisation to each other.

The shift of perspective from a core product-oriented view to a service-oriented view represents a gap in knowledge for manufacturing companies (Ericson & Larsson 2005). The knowledge and competencies in manufacturing companies are directed at embedding knowledge into a physical product. With PSS approaches, knowledge and competencies can be aimed directly at the customer's activities or through the education and training of the customer (Sandberg & Werr 2003). Value is not the only entity created in the interaction with the customer during a product's use phase; new insights about the product and an understanding of customers, their context and value perception are also attained. If captured and integrated into the providing company's organisation these insights can be a vital source of competitive

advantage. The shift to more service-oriented approaches induces changes in how manufacturers can deliver more value to their customers, or operate more efficiently themselves in relation to what customers want. These changes point to new innovation mechanisms and possibilities that traditional technological product-orientation would not be capable of delivering.

Typically a company's development activities are derived (top-down) from the company's overall corporate strategies in relation to its position on the marketplace. This assumes that industry structures are relatively stable (Porter 1985) and that products can easily be compared on specific parameters, (e.g. price, size, weight, etc.). PSS approaches attempt to uncover new relationships and different networks of actors. The markets in which PSS companies operate on are not as stable in comparison, as they will rapidly follow emerging opportunities. Often the determining competitive advantage will be based on the forming and orchestration of new actor networks that can provide unique value to the customer (Manzini et al. 2004).

A PSS development model is therefore not about rejecting and redefining current product development; products will still need to be developed on their own, but the new model should resolve how product and service development ought to be carried out with PSS approaches. Observations from a service-oriented development project in a large global manufacturing firm (Case study B: Steelcase) help to determine how the development system for PSS can be modelled (Tan et al. 2007). For more information on the case study, see Chapter 4.

5.6.2 Insights to product and service development activities in a manufacturing firm (Steelcase)

In order to get an understanding of the development activities in a manufacturing firm, the author carried out a '*participant observation*' case study with Steelcase, a large global office furniture manufacturer, on a development project over a period of 15 months (see Chapter 4, section 4.2). The objective of the development project was to demonstrate how the company could support the move from doing business based on *product sales* to business based on the achievement of *sustainable office workspace performance*, related to activities in the physical work environment. The project had its base in the company's corporate research department (WorkSpace Futures) and was aimed at the company's corporate consultants (Applied Research Consultants), and also had close ties to the company's sustainability department, international marketing, corporate marketing as well as a joint venture subsidiary (Workstage). As the project had many interfaces to different parts of the organisation the author came into contact with several of the company's functional units and could thereby gain insight to how they worked together. Both WorkSpace Futures and the Applied Research

Consultants operate globally so an international and corporate perspective was taken in the project.

Following their commitment to the environment, Steelcase has worked intensively since 2001 with Eco-design/Design for Environment and Life Cycle Assessment (LCA) methods – to such an extent that they issue comprehensive Environmental Product Declarations on all their products. In order to continue to live up to their commitment to protect the environment they have recently asked themselves, *“what should be the next steps?”* Steelcase acknowledges that their focus on office furniture (chairs, desks, storage units, etc.) is not sufficient enough to achieve substantial global environmental improvements. They have to consider the whole office environment and relate this directly to the users of the workspace. Although furniture typically has the greatest environmental impact in its material and production phases, compared to lighting, computers, heat and ventilation, which are energy-using products; the total environmental impact of furniture is just a fraction of the whole workspace environment. In collaboration with École Centrale Paris and the French Environment and Energy Management Agency (ADEME) Steelcase initiated a project *“to develop a computer based information system linking workspace design with business results and sustainability performance (in economic, environmental and social terms) to support decision making when planning office workspace”* (Boughnim et al. 2006).

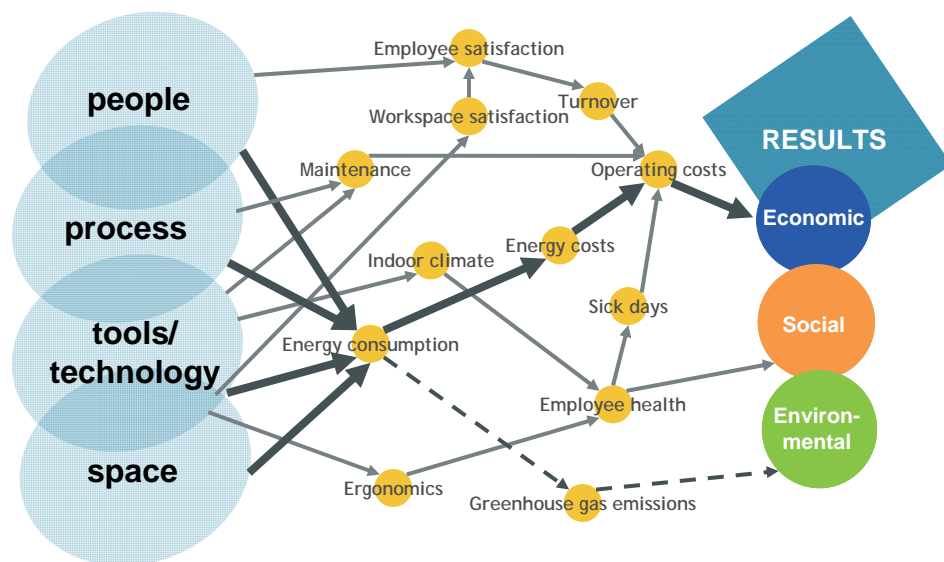


Figure 5.9 The general principle (only limited correlations shown) behind the computer based information system tool, showing correlations between technical elements in workspace design (on the left) in relation to sustainable performance (on the right).

The ultimate objective of the project was to demonstrate and actively engage Steelcase’s clients to show that the physical office workspace has economic, environmental and social impacts vital to their clients’ strategy and business performance (see Figure 5.9). The idea was to

position Steelcase as an expert on all activities related to the physical workspace and not just an office furniture manufacturer.

Observations

With the acquisition of the renowned design consultancy, IDEO, in 1996, Steelcase has developed user-centred design to be one of its key strategic competencies. User-led insights form the basis for the development of their products, services and even new business ventures:

- In product development a new product is often developed based on how to best support an observed activity or task in the office workspace, and not just on redesigning existing furniture (see Figure 5.10).
- Their range of services is mapped out according to the cycle of customer's activities when planning a new workspace (see Figure 4.4).
- The corporate consulting, ARC, team uses a user-centred methodology for engaging users in the design of new workspace.
- Nurture, a new thriving business unit, was established based on insights from their user-centred design methodology applied to healthcare work environments.

Although these many development activities share a common basis they are developed in different parts of the organisation in projects that are independent of each other.

Part of Steelcase's interest in getting more involved with their customers' use of their products is that they want to position themselves as strategic partners in order to avoid pure cost-based competition during product sales. With only products it is difficult to maintain good customer relations over time, as major customer purchases tend to be periodical with several years between each. Some of their customers are major multinational corporations which only want to deal with one preferred supplier and expect Steelcase to provide furniture and related services around the world. In order to serve its customers Steelcase has an extensive network of independent and company owned dealers around the world. This allows them to be in close local contact with their customers when needed. With key strategic customers, emphasis is placed on how the Steelcase can maintain close relations with them through on-going development projects. Typically these development projects would be projects that incrementally improved the customer's activities, but they could also be larger more radical and innovative partnering ventures. Steelcase regularly partners with other companies and organisations. These could be together with:

- *architect and design firms* to design and plan new office buildings and work places for clients.
- other *office equipment manufacturers* (e.g. Canon (imaging equipment and information systems) and Armstrong (floors,

ceiling and cabinets)) to do technology research or develop and provide new combinations of products.

- *universities and research institutions* to do research in how to help people work more effectively.

These partnerships allow both parties to benefit from each others competencies and also help gain access to customers. It is interesting that Steelcase can have multiple roles with their partners, some times they are just product suppliers or service providers, some times equal strategic partners and some times even in competition with them in certain areas. Besides engaging in design and development activities with partners, Steelcase also designs together with their customers, as the nature of the ARC team's services is to design and plan with customers as part of the consulting process. Several methods of capturing information about customer activities, and then analysing and communicating insights were observed in the company:

- User observations and insights achieved by WSF researchers through their user-centred design process are shared with others through '*design charettes*.' These are design workshops where those individuals and departments responsible for developing new products and business ventures work together with the researchers to generate new ideas and concepts that they can continue with.
- The ARC team has a set of on-line survey-based tools that can gather rich information of the way people work, covering different aspects such as work place satisfaction, mobility, internal organisational network, etc. The results are collected and analysed according to best practices and identifying potential areas of improvement.
- The ARC team also use anthropological and ethnographic information collection techniques with their customers and then organise space planning workshops where the gathered information is processed and solutions are co-designed with users. This gives Steelcase considerable insights to their customer's work place and behaviour. The insights are then typically shared in case studies and white papers (e.g. (Barros et al. 2006)).
- The Workplace Services team continuously track the performance of their services and benchmark them according to indicators of how well they are managing their customers' furniture and changes to the work place. This allows them to document how they are helping their customers reduce their costs and understanding the cost structure of using and handling office furniture.

Even though Steelcase has many of these knowledge management systems and practices in place, it is however still a challenge to ensure

project ownership and proper knowledge transfer every time information is passed on. The observations made in Steelcase regarding strategic competencies and partnerships; development activities with partners and customer; and, information and knowledge management form a base for a model for PSS development.

User-centred design

By studying how small teams share information on their computer with each other in meetings, Steelcase noted that it was cumbersome and time-consuming each time participants wanted to project information from their computer on to a screen as the cable for the video projector had to be passed on and connected. Steelcase designed a solution to cater for this by connecting everybody with each their own cable so they could pass the control by simply pressing a button. In addition, two screens (situated at the same height as the participants) were used instead of one, as this allowed all the participants to maintain eye contact with each other whilst following the presentation.

High chairs so all participants are at the same eye height as the flatscreens no matter if they are sitting or standing

Two flatscreens

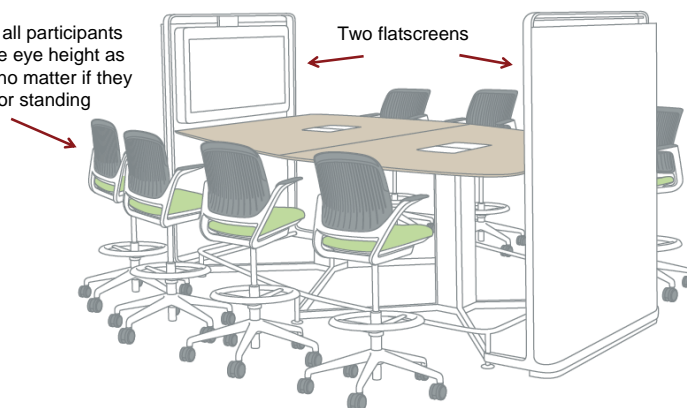


Figure 5.10 The *media:scape* is a result of user observations and an example of how Steelcase develops their products (Steelcase 2008).

5.6.3 A model for PSS development activities

The themes investigated above show how PSS challenge traditional practices of product development in a manufacturing company's context. Here PSS development is more closely related to business development than product development. In order to develop PSS, manufacturers must consider involving customers, suppliers and other partners on three levels: when strategically partnering and creating new networks, in development projects and on an operational level.

PSS approaches do not entail that all development projects will be integrated product and service development projects. Pure product development projects and pure service development projects will always exist, but with PSS approaches the projects will take into account how products and services can mutually support each other. Most of these considerations will however take place in the conceptualisation phase or even be determined on a product planning or business development level.

The PSS development model (Figure 5.11) shows on what levels customer and partner co-development occur. Development activities take place on multiple levels in the organisation. Partnering opportunities with customers, suppliers, distributors, etc. are investigated, initiated and maintained on a *strategic level*. *Business development and product planning* determine which product and service development projects are initiated and how they relate to each other. The product development process is the *executing level* for most of the development tasks. On a project level development a company may

choose to co-design with customers, partners or both. *Information* that has been captured from the operation of their products and customer activities is analysed and used to inform both portfolio management and the individual development projects. Finally development activities can also happen on a *customer operations level* as ongoing customisation. These development activities are however performed on an already developed service platform.

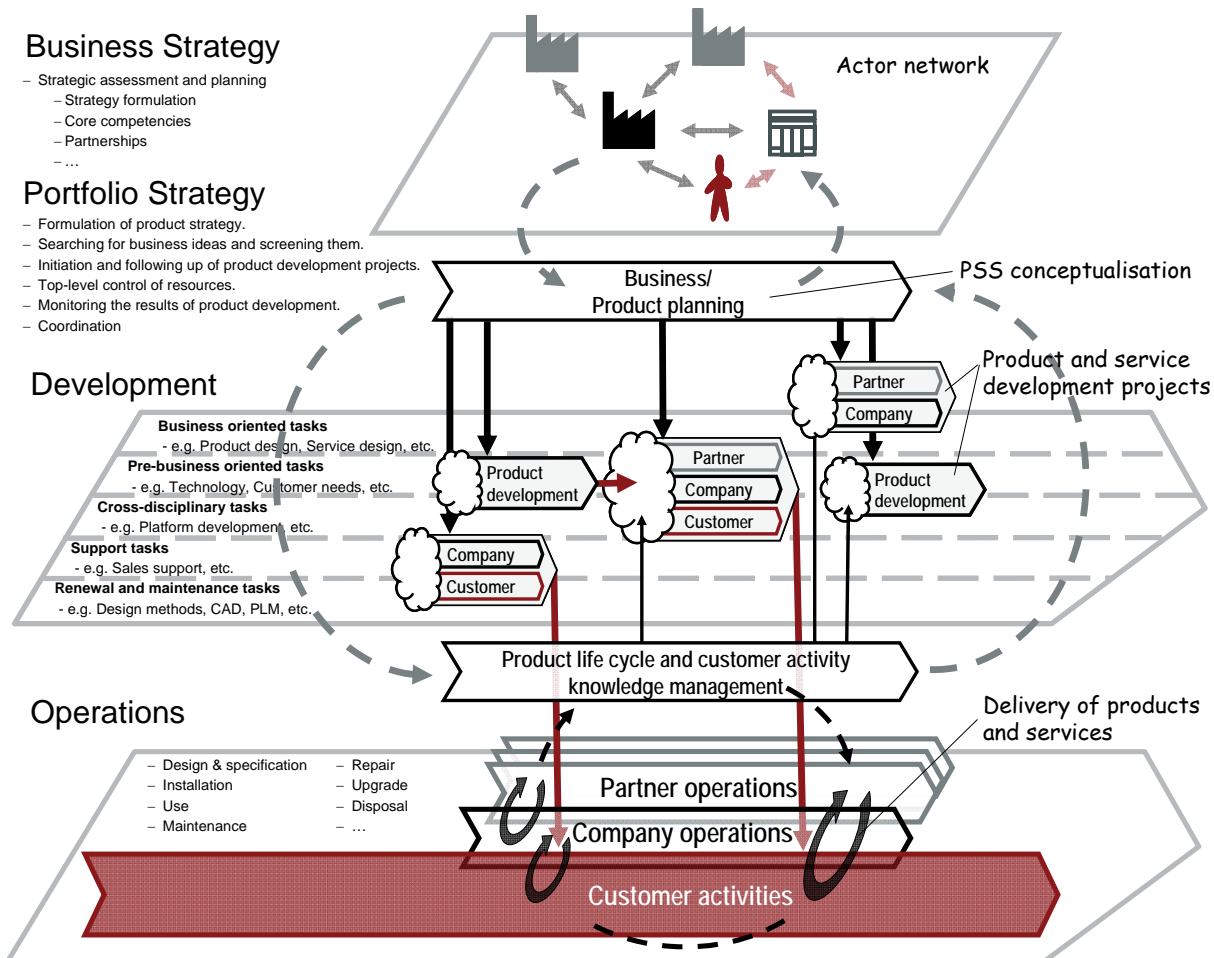


Figure 5.11 A model for PSS development showing design and development activities on multiple levels of the organisation of a manufacturing firm.

Establishing and managing the actor network is crucial to enabling the PSS and its development to function. As PSS do provide better access to customer's activities a structured and systematic process for information gathering, storage and analysis has to be in place in order for business development and development projects can leverage the insights gained.

In the PSS development model PSS concepts are developed on a portfolio strategy level whilst the product and service elements are developed individually in structured development projects. When the development conditions and requirements of a product or service and how they related to each other is defined during business planning then

development can proceed in manner that is similar to Integrated Product Development.

On an individual (development) project level PSS approaches are not expected to entail much difference compared to IPD on how projects are structured and managed. Development projects will still follow the basic stage-gate approach from need investigation, concept development, detail design, testing and implementation (Andreasen & Hein 2000; Cooper 2001; Ulrich & Eppinger 2003). The methods and processes for investigating, specifying, generating, evaluating and testing do not change with PSS. What does change is the context in which the development project is, how it relates to the business and other projects and who contributes in the development process.

An interesting aspect of this model is that it attempts to visualise aspects of product development that already is common practice in companies today, but has not been integrated. Most companies work closely with their suppliers and already co-develop with them (TEKES 1999). Customer Relationship Management, Product Life Cycle Management and Supply Chain Management systems already collect data on customers, products and suppliers respectively, but do not do so in an integrated manner.

Integration in this model of PSS development can be understood on:

- a *business strategy level* where actors can identify opportunities to work towards the same business goal
- a *business planning level* which coordinates development activities based on the company's strategy and competencies as well as the competencies accessed through strategic partners.
- a *project level* where partners and customers are part of the development process with defined roles and responsibilities.
- an *operations level* where the company, partner and customer activities are coupled with each other to provide services.

The model shows a general structure of development activities and how they are integrated. The structuring of the development system, e.g. where in the organisation the individual product and service development projects are carried out, are not defined, as this should be based on the specific development objectives and tasks (Sant 1988). However the main essence of IPD – being the timing, value-added, risk-minimising, competence-integrating activities in a coordinated and repeatable fashion – still holds when we consider PSS development. The difference in this situation is that new parallel activities become apparent and the '*front-loaded*' activities of PSS development dominate the later activities of detail design and manufacturing in a new way.

5.7 PSS development strategies

The *Model for PSS Development* presented in the previous section accounts for the various development activities related to PSS. As can be seen in Figure 5.11 these activities happen on different levels of the organisation involving multiple actors and occur at different times and intervals. PSS approaches are a set of coordinated strategies in a company but also for an entire network of suppliers, partners and customers. This is the perspective that is taken in Figure 5.12.

The case study on Steelcase provides an example of how development activities are related to each other. Steelcase leverages its core competency in user-centred design to develop new products, services and even businesses in many different parts of the organisation. Given the high purchase cost of furniture and frequent changes in the users' work environment, Steelcase follows a strategy of designing and providing high quality furniture durable furniture that has a long life. From an environmental point of view the greatest impacts of office furniture are in material extraction and production, and the most appropriate resource efficiency strategy is to prolong and increase the furniture's utility. Steelcase supports this by:

- employing Design for Environment methodologies that ensure that their products are easy to repair and refurbish;
- providing work place services that manage assets and furniture maintenance;
- emphasising space planning and its influence on achieving business results through consulting that ensure customers have the space that best supports them; and,
- take-back programmes with partners that allow furniture to be refurbished and resold or donated to charities, community groups, etc.

In the above, it is apparent that the effects of e.g. ease of repair and refurbishing can enhance the value of the product for the customer, as well as allow activities such as work place services and take-back programmes to be more efficient. Furthermore by gaining access to customer's sites through services, Steelcase can develop strong relations with their customers and increase the chances of more business with them. PSS development is therefore about the careful consideration of how an opportunity in one area of the business can be leverage on in others, so a coordinated strategy may be applied. This is in essence what the aforementioned opportunity parameters represent: mechanisms for manufacturing firms to identify new innovation possibilities.

In order to achieve the full potential of PSS development and delivery, coordinated and integrated strategies need to be in place. These strategies must be in place to ensure that the value chains are capable of

supporting customers and their activities throughout the products' life. PSS business strategies however do not only relate to the manufacturer's organisation, but should also align the entire actor network surrounding the PSS.

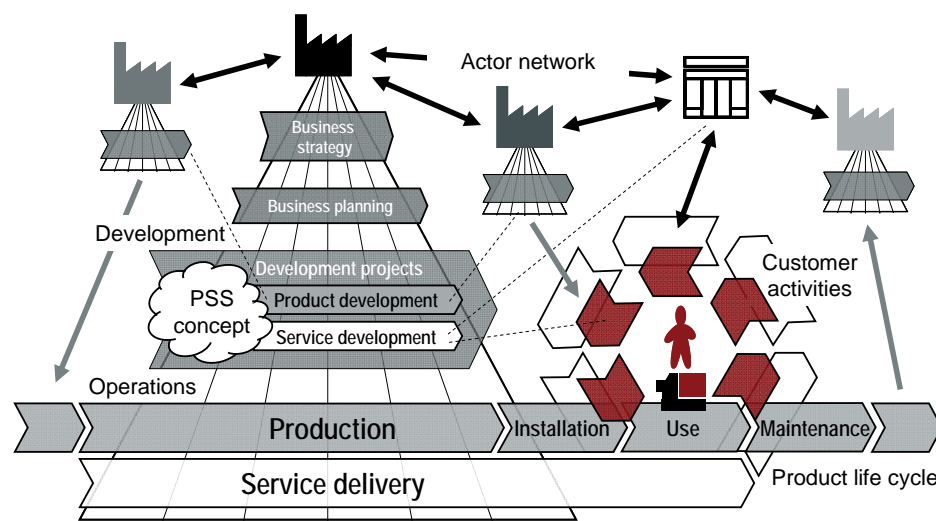


Figure 5.12 The business strategy perspective of PSS in a manufacturing company's organisation. PSS development call for coordinated and integrated approaches on all levels of the organisation. The result of PSS development supports the customer and his/her activities throughout the product's life. The network of actors is also engaged in the development and delivery of PSS. (The illustration is inspired by Larsson's reference model for portfolio management (Larsson 2007)).

PSS approaches emphasise the importance of coordinating strategies which includes those of the customer and other partners. Figure 5.12 is modelled on the level of a business unit and not a corporate strategy that could encompass many different business areas. It is not possible to see in this model whether the product-oriented business and the service oriented-business should be separated into different business units or kept integrated. Both are possibilities for manufacturers to organise themselves for PSS. If a company decides to create an independent customer focused service-oriented organisation this would then just be modelled as an actor in the network that would have close relations with the customer.

5.8 Summary

This chapter has presented theoretical frameworks for understanding PSS in relation to the (conceptual) design object (Figure 5.5), design process (Figure 5.11) and integrated business strategy (Figure 5.12). The frameworks are built upon well-established theories in Engineering Design and Product Development as well as observations made during a participatory case study in a service development project in a manufacturing firm (Steelcase). The frameworks have been explained, but their applicability has not been fully validated. This will be done in the following chapters and discussed in Chapter 8.

The formulation of frameworks provides a theoretical foundation to the first research question: *“how can PSS be understood compared to traditional product development?”* The following can be noted:

- PSS approaches have the following attributes:
 - Life cycle orientation
 - Customer and customer activity focus
 - Systems thinking
 - Interdisciplinary
 - Competitive business strategy
 - Sustainability perspective
- **A PSS as a design object is not just a technical system but a total transformation system and the providing company's (or companies') responsibility for its effects.**
 - Although Hubka's (Hubka & Eder 1988) Transformation Model models product (life) related activities well, the customer activity cycle also needs to be considered in PSS.
 - The actor network perspective provides an explanation for the motivations and incitements of the individual actors (or operators) that influence the transformation system.
 - Besides the product itself three perspectives: product life phase systems, customer activities and actor network, seem to form the essential dimensions of PSS conceptualisation.
 - Based on these conceptual dimensions and lending methods from other areas three design techniques that support the systematic conceptualisation of PSS were suggested:
 - Product Life Gallery
 - Customer Activity Cycle Modelling
 - Actor Network Modelling
- PSS development is different to traditional product development with regards to:
 - the focus on activities instead of products as the mediator of value – the development and providing activities within a company should be aligned with their customers' activities.
 - the involvement of the customer and other partners in the design process.
 - the redistribution of role and responsibility as the company takes greater responsibility of its products and also customer activities.
 - the expansion of competencies required to offer and deliver PSS solutions – how should the partnerships with external companies be integrated.
 - the integration of products and services – the development of the total range of products and services that are offered should be coordinated.

- the need for a structured, systematic and formalised approach to capturing, storing and analysing data about the product's use.
- the closer strategic relations between the actors in a PSS and how all the development activities are integrated and coordinated.
- **A PSS as a design process is a set of coordinated development activities at strategic, tactical and operational levels of the providing company (or companies) including the customer activities.**
 - The model for PSS development shows development activities occur during operations (based on a service platform), in the development projects of products and services, during the product and service development process, business/product planning and strategy formulation.
 - The characteristics of services involve the customer in the co-creation of value – the role of marketing, production and design in manufacturing firms should be prepared for increased user-orientation activities during the development process.
- **PSS approaches as integrated business strategies are a set of strategies (i.e. business strategy, product strategy, service strategy) coordinated internally in an organisation but also externally with customers, suppliers and other partners.**
 - The expansion of competencies required to offer and deliver PSS solutions – how should the partnerships with external companies be integrated.
 - The development and providing activities within a company should be aligned with their customers' activities.
 - The integration of products and services – the development of the total range of products and services that are offered should be coordinated.
- By using the 'language' and 'paradigm' of Engineering Design the conceptual frameworks and methods presented seem to encourage a systematic pursuit of new solutions, but this needs to be verified by applying them to empirical case studies to see if they are able to identify and articulate the conceptual aspects of a PSS appropriately.

6 PSS conceptualisation

The shift in perspective from product-orientation to service-orientation represents a challenge for designers. Traditionally, the focus of design disciplines has been on physical artefacts rather than on services (Morelli 2003). With PSS the designer has to understand a broader scope of customer (and stakeholder) value dimensions that are traditionally not considered in product development; e.g. user involvement, interaction experience, integration of systems, domestication (how new technology is appropriated by users), service delivery channel, after sales service, upgrading, ease of disposal, etc. (Andreasen 2002). In the light of this PSS calls for a need to expand both the traditional Engineering Design mindset, in order to be able to understand the proper nature of PSS, and the expanded degrees of freedom in design, in order to carry out professional systematic PSS design.

This chapter investigates the second research question further: *how may PSS be conceptualised?* The answer to this question should be coherent with the operational understanding of design concepts in general. Here based on Hansen and Andreasen (2003) three aspects of conceptualisation are considered:

- The *identification and articulation of the conceptual aspects* of a PSS
- The *evaluation criteria* for a good PSS concept
- *Modelling* of PSS concepts

Based on the theoretical framework presented in the previous chapter which suggests that product life phase systems, customer activities and the actor network are the fundamental dimensions of PSS design concepts, the case studies carried out in this thesis are analysed to provide empirical insight to the conceptualisation of PSS.

6.1 The nature and content of conceptualisation

Design concepts are proposals for products or services that are brought to a certain level of concretisation. According to Hansen and Andreasen (2005), the following dimensions are typically used to articulated design concepts in literature:

- *Strategy*, mission, vision, etc.
- *Business*, target market, business goal, demand, market potential, etc.
- *Need*, customers, product attributes, customer problem, etc.
- *User, customer*, behaviour, response, values, etc.
- *Technology*, product principles, production method, etc.
- *Product*, working principles, form, appearance, technical solutions, etc.
- *Task*, problem, contract, etc.

- **Goal specification**, features, cost goal, functionality, properties, performance, etc.

However, the authors do point out that it is not necessary to describe all these dimensions during conceptualisation, but rather identify and focus on the “*difference that matters*”. Later in the design process these dimensions do need to be completely defined, but when conceptualising it is sufficient to only consider a subset of these.

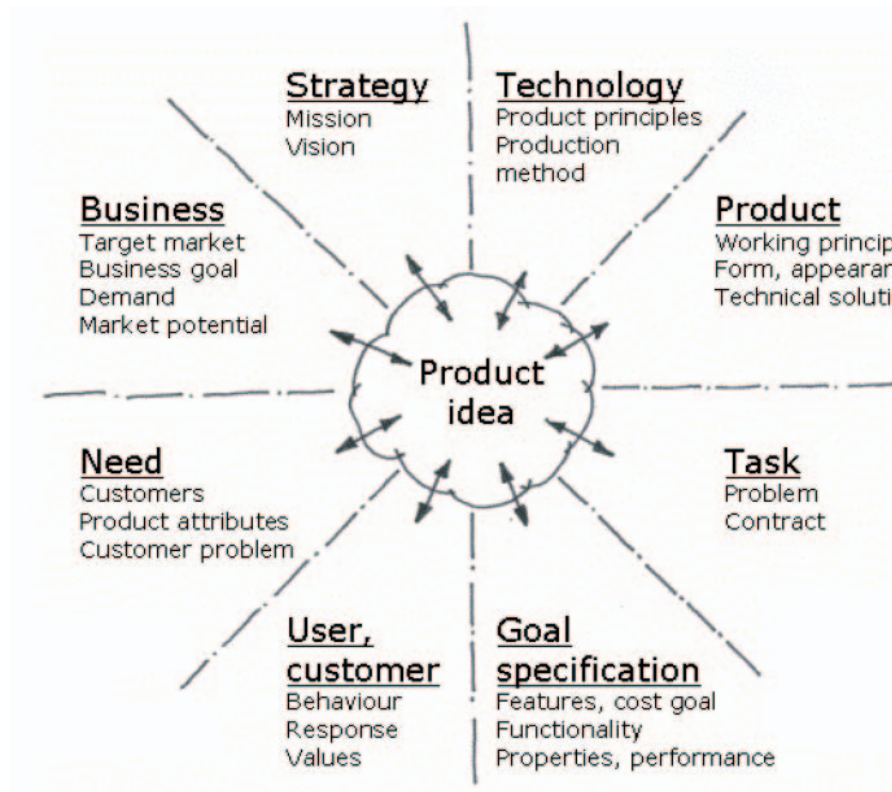


Figure 6.1 Hansen and Andreassen's (2005) framework for describing a product idea which will also be compared with this thesis' proposed articulation of PSS concepts.

Fundamentally though, there are two types of descriptions of a concept which mirror each other, one that expresses the need/market-based aspects (“*the idea with*”) and the other that explains the design/realisation-based aspects (“*the idea in*”) (Hansen & Andreassen 2003). As was established in Chapter 2 (section 2.3) products and services are merely two modes for companies to deliver value to their customers that may be configured in any way to provide a value proposition. A value proposition that is defined and formulated is therefore equivalent to the need/market-based description of a concept whether it is a product, a service or a PSS. The task that remains is therefore to determine whether a description of the *product life phase systems*, *customer activities* and *actor network* sufficiently describes the design/realisation-based aspects of a PSS concept. In the following these three conceptual PSS dimensions are applied in the case studies.

PSS approaches are seen as a potential for more sustainable solutions to satisfy needs and generate business. For this reason PSS concepts must be able to demonstrate their sustainability potential and explain how these can be achieved. Accordingly the evaluation criteria of PSS concepts should go beyond the criteria dimensions as suggested by Hansen and Andreasen (2003) for *a profitable business*, *a good product* for the user and *a tractable process* for the design team, but also include *a resource efficient and equitable solution* for society (Tan & McAloone 2006a).

It is fundamental to be able to model concepts in order to communicate and analyse design objects whilst they are still abstract (see Chapter 5, section 5.5). The PSS design tools, presented at the end of the previous chapter, serve as a set of modelling techniques for each of the PSS conceptual design dimensions. These were used as graphical visualisations in the case studies and thereby served as *boundary objects* (Star & Griesemer 1989) that helped communicate and explain the PSS ideas amongst the different people involved in each case. The following reflects on these experiences of using these visualisation techniques.

6.2 The application of a PSS Conceptualisation Methodology

As PSS approaches represent new opportunities for business for manufacturing firms, PSS development is more closely related to business development than product development (see Chapter 5, section 5.6). The responsibility for developing PSS concepts lies on a portfolio strategy level where ideas for new business models are developed based on the organisation's strategy, core competencies and relations to customers and other partners. The PSS Conceptualisation Methodology presented in this thesis is proposed to support cross-functional teams in the early conceptual phases of new business development where integrated products and services are defined. It takes an existing product or service as a point of reference. In this way the performance of new solutions can be compared existing offerings to determine whether the same (or better) benefits can be achieved whilst increasing customer value and reducing the environmental burden (the so-called *Factor X improvements* necessary in sustainable development (Schmidt-Bleek 1997)). In other words the starting point for the methodology is the value proposition, or rather the multiple perceptions of value by each actor, first based on the existing product or service, then on how to develop a PSS with a value proposition that better satisfies all the involved actors. Focusing only on design changes in the technical product will usually only bring a limited factor improvement, but changing product life phase systems (or infrastructure) and user behaviour has the potential for much greater improvements (Brezet et al. 1999). PSS design attempts to identify not only the changes to the product, but what changes can be made to the entire production and

consumption system and how stakeholders' motivations and incitements can be aligned.

The three PSS perspectives, product life phase systems, customer activities and actor network (see Chapter 5, section 5.4) may be regarded as expansions of traditional design. These perspectives can be understood through individual analysis and reconfigured through collective synthesis to arrive at innovative system solutions. The design process is iterative in its nature, going through steps of analysis, synthesis and evaluation. The process used in the following three cases is based on the EDIP (Environmental Design of Industrial Products) research project approach (Olesen et al. 1996). Here the process steps are: 1) *Analysis and Diagnosis*, 2) *Focus and Goal setting*, 3) *Conceptualisation* and 4) *Evaluation*. Each of the three PSS dimensions is considered at each of these steps (see Figure 6.2) with the value proposition (or “*idea with*”) as a point of reference for conceptualisation (see Chapter 2, section 2.2). In the following this PSS Conceptualisation Methodology is explained in greater detail.

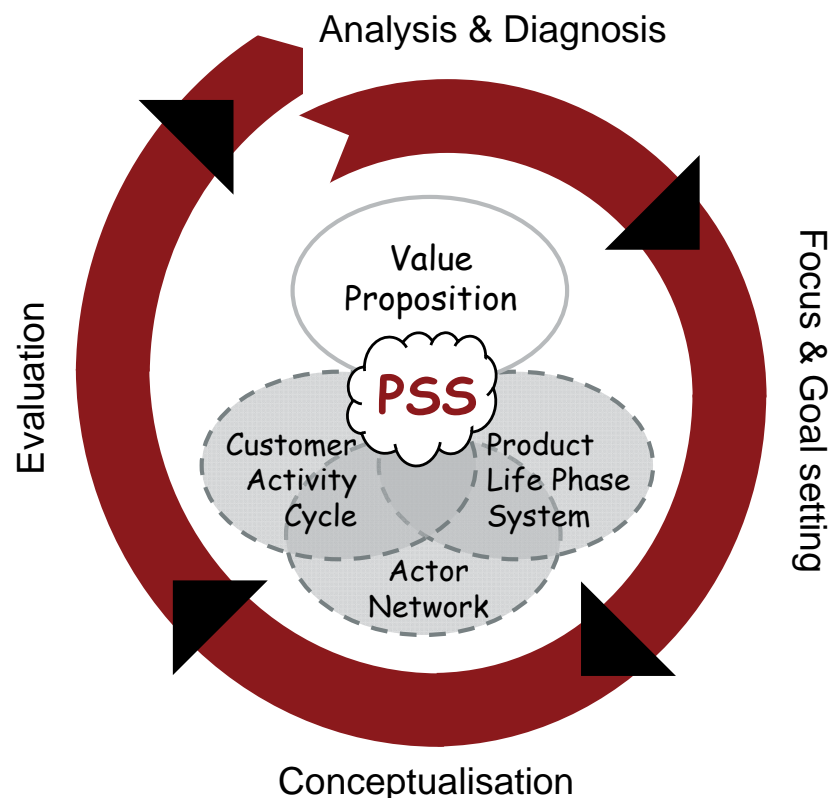


Figure 6.2 The PSS Conceptualisation Methodology. The figure shows that PSS conceptualisation is guided by the *value proposition*. It then considers where changes may be made in the three PSS dimensions: *product life phase systems*, *customer activities* and *actor network* to create new innovative concepts.

6.2.1 Analysis & Diagnosis

Designers should not design blindly. They need to understand the impacts of products and services (e.g. through the Universal Virtues:

cost, quality, flexibility, risk, environmental effects, etc. (Olesen 1992)) in relation to the value that they provide, before attempting to change existing systems. A thorough analysis of the existing products and services is therefore required. This could be value/cost analyses, abridged environmental life cycle analyses, user observations, etc. Information must be gathered from multiple sources to create deep insight into the product's life cycle, customer activities and the range of actors surrounding the product and customer activity. These deep insights in use situations and contexts are typically not collected in marketing teams (Ingram et al. 2007). During the analysis and diagnosis designers should achieve a good understanding of the current product or service, actors and life cycle systems and how these effects are related to what is determined during design. A Product Life Gallery (see section 5.5.1) could be used to structure and visualise all this information. After performing this task the PSS conceptualisation team should be able to identify what degrees of freedom are at their disposal and rapidly put together scenarios for the multitude of possible solutions.

6.2.2 Focusing & Goal Setting

Resources are limited and companies cannot initiate new development projects on every good idea they get. With limited resources it is necessary to prioritise at an early stage amongst the many directions in which the PSS conceptualisation team may pursue. By performing the analysis and diagnosis the team should have sufficient knowledge to assess which general design strategies and solutions are the most promising in relation to change and effect. Many environmental effects are unavoidable with current technologies and practices, so the objective is to identify the areas where change may happen, i.e. identifying the degrees of freedom. In other words which of the PSS dimensions should they put their effort to achieve the biggest gains. Feasible goals are then set to which solutions will be further conceptualised and how the value and environmental improvements may be achieved are described.

6.2.3 Conceptualisation

Concepts are proposals for products and services that describe the most important features and requirements of the final offering (Hansen & Andreasen 2005). During the early stages of product development when not many costs have incurred, decisions are made that will determine the greatest part of the costs later on in the project (Andreasen & Hein 2000). It is widely recognised that adequate time should be spent on product and/or service definition. Conceptualisation allows the development teams to form an overview of a number of integrated PSS concepts. Here all relevant dimensions should be sufficiently described and unknown risks investigated. Multiple concepts should be developed to increase the possibility of identifying the best idea. Each PSS concept should consider the value proposition or the *"idea with"* the offering and

the three “*idea in*” PSS dimensions: product life phase systems, customer activities and actor network, and how they collectively support each other to frame a total integrated system solution. PSS solutions are often radically different from existing solutions and might require a redefinition of a company’s existing business model, so considerable thought also has to go into how the transition to a new innovative system can best be encouraged and supported.

6.2.4 Evaluation

There is no absolute best solution. It is only when comparing two promising solutions that one can determine, what would be the most sustainable solution to proceed with. The existing production and consumption system of the product or service is used as a baseline for comparison. If a concept does not seem to provide substantially improved value and environmental performance it should be reconsidered and other concepts explored further. PSS approaches seek to achieve radical improvements in several dimensions - not just environmental. Concepts that are mainly characterised by novelty, but are otherwise incremental improvements at best should be discouraged as this would just require unnecessary use of valuable resources.

6.2.5 Using the PSS Conceptualisation Methodology

The PSS Conceptualisation Methodology presented above was originally developed specifically for the DTU PSS design project course by McAloone (2006) (case study A). Over the past five years it has been refined in the course with models, methods and techniques to aid PSS design. In 2008 the methodology was applied by the author in two companies – case studies C (Vitsø) and D (RiverSimple). The following excerpts capture the experiences from the application of the design methodology. For more about the case studies, see Chapter 4.

Case study A: PSS Design Course

The observations below are drawn from the author’s involvement over three years in the teaching and evaluation of the PSS design course at DTU (from 2005 to 2007). The experiences and reflections of the course were regularly discussed with the other teachers in the course, students and external examiners. They are therefore not just a result of the researcher’s own personal thoughts (Tan et al. forthcoming).

The aim of the course is to create PSS concepts with radical environmental improvements without compromising the customer perceived value. During analysis and diagnosis the students uncovered what trade-offs are made between attributes of the existing product and its life phase system. These are not always given (e.g. better quality does not necessarily entail higher cost) but depend on the context and nature of the solution. However, when generating PSS solutions many students found it challenging to break the perceived link that certain Design for

Environment strategies can only be achieved by e.g. increasing the cost or settling for lower quality standards. It is only when the perception of the system's degrees of freedom are expanded, did the students begin to find it easier to identify possible solutions. This was done by redefining the system dimensions of value perception (e.g. giving less significance to traditional attributes that do not hold much value), life cycle (e.g. considering the total costs over a product's life), customer activities (e.g. linking otherwise separate activities in a more effective manner) and/or actor network (e.g. involving a new actor that is interested in providing or deriving value from the system).

During the first part of the course the students were asked to identify and understand environmental issues through all the life phases of a reference product or system. The students gathered information from a variety of sources; interacting with the product themselves (dismantling if possible), related documentation (sales brochures, technical specifications, manuals, etc.), internet searches, contacting the manufacturer or operator, observing the product and its context in use as well as interviewing relevant stakeholders. The Product Life Gallery technique (McAloone 2007) proved to be an effective way to navigate, capture and structure the large amounts of information, and it allowed this to be easily shared (see section 5.5.1). Even though the students were introduced to abridged life cycle analysis tools, they were surprised to discover that it was not always easy to access environmental data. By performing their own environmental analysis they learnt to be critical about how companies state the environmental profile of their products in relation to real life use. Following the various actors' activities they often also discovered through interviews and observations how certain (environmentally adverse) behaviours are not taken in to account.

In their course evaluations the students did express that the considerable effort put into analysing and understanding the reference product was sometimes not always related to their final PSS concepts, i.e. their PSS solutions were only indirectly related to the original reference product. This is often true with products where the constraints of the existing system or its actors did not allow for much 'design manoeuvrability'. Solutions then had to be found beyond the reference product itself and among the associated actors, activities, products and supporting systems that influenced the product's system. When this was the case, students felt that their initial analysis efforts had been 'wasted' as it would have been better to focus on what was 'designable' from the beginning. This may be substantiated as the course did have to adhere to certain learning objectives. Although this might not seem the most efficient manner to get to a solution, the teachers/researchers contend that this delayed discovery of the degrees of freedom is vital to knowing what to design and a crucial part of the PSS design process.

Although a classroom setting with engineering students is not a sufficient empirical gauge for the real life utility of a design methodology, it does help refine it and give pointers in the right direction. The analysis of value proposition(s) and the three dimensions of PSS; product life phase systems; customer activities; and the actor network seemed to describe the essential design perspectives of a PSS. Furthermore, when each of the dimensions was determined and coherent with each other, the entire PSS concept did seem to be well described and form a comprehensive whole. This was in particular evident when the student groups each effectively presented their PSS concepts in less than 10 minutes at the end of the semester to the course instructors, other classmates, external examiners and others (e.g. company and municipality representatives). Here, when the PSS concepts were described in the three dimensions and modelled using the visual techniques (see section 5.5 for a description of the techniques used) they were easily communicated and understood by to others. In subsequent bachelor and master thesis projects (that were not necessarily related to PSS) it was noticed that many of the students who had taken the PSS design course continued to use these techniques.

The three dimensions also seem to provide a fair basis to evaluate PSS design concepts. The product life phase system perspective informs on the environmental impacts and the efficiency on natural resources in both production and consumption. The customer (or user) activity perspective provides an idea of the benefits the PSS actually brings to the individual and how their needs are satisfied. The actor network brings together all the actors that are involved throughout the product's life and along the customer's activities. This perspective describes how they are related to each other and why they are motivated to engage to do business with each other. Finally by comparing the description of the existing system to an imagined and improved PSS the (design) tasks necessary to be performed can be identified. These can be changes to the product, changes to a life phase system (e.g. infrastructure), changes to customer activities or changes to the actor network.

Case study C: Vitsø

The first company the PSS Conceptualisation Methodology was applied at was the small design furniture company, Vitsø. This was done through four design workshops, representing each of the steps of the methodology. Compared to the PSS design course, this was a much more intensive and focused design process. Vitsø was actively engaged throughout the process and had a clear vision in which service-oriented directions they were looking for solutions.

During the first workshop three characteristic customer types were identified and the value perception, customer activity cycle, product life and actor network were mapped out for each of them. Here the same

graphical visualisation models used in the PSS Design course were used to gather and structure information. These proved to be very effective for the purpose, but even so within the three hours that was allocated for the workshop, only two of the characteristic customer scenarios were scrutinised with most time spent on the value proposition and customer activity cycle. Interestingly enough based on the detailed information gathered on the customer activity cycle it was relatively easy to derive the information needed to draw the product life cycle and actor network after the workshop.

Not all of the PSS design dimensions were investigated in depth. Besides prolonging the product's life for as long as possible, the product and its life cycle were not given much consideration as these aspects were already well established in the company. The search for solutions were predominantly in how to sustain customer satisfaction (a customer activity cycle perspective) and how to systematically leverage upon the loyalty of existing customers to get potential customers interested in Vitsø (actor network perspective). Although the PSS dimensions mirror each other, each perspective allowed the company to focus on different ideas in the direction they were interested in.

The second workshop was framed more as a brainstorming and idea generation session than the originally intended *Focusing & Goal setting*, but as Vitsø had a clear vision and values they could from the start already point out which directions they sought new concepts. Despite the methodology being structured as four distinct steps, the actual design process was very much iterative with simultaneous analysis and synthesis of ideas. Nine PSS ideas were prepared for the third workshop. These ideas were all equally elaborated as individual concepts and for each their main features regarding costs, benefits and risks in relation to Vitsø, customers and any other potential actors were described. During this workshop the implications of each concept was discussed and finally three concepts were selected to be further developed. At this stage not all PSS perspectives were needed to describe the concepts, but it was noted that the perspectives did support the creative concept generation process.

The fourth and final workshop was a final presentation and evaluation of the three selected concepts that were elaborated and made as credible and feasible as possible. At this workshop the concepts were presented to other employees at Vitsø than those that were directly involved in the design process to discuss which concept should be implemented first.

An interesting aspect that emerged from the conceptualisation process with Vitsø was that the transfer of product ownership from company to customer was not necessarily in opposition of prolonging the product's life, as is typically mentioned in PSS literature. Vitsø's products are

particular in the way they are design icons that customers develop an emotional attachment with, so customer ownership actually fosters long product use (similar to the ideas of Jonathan Chapman (2005)). Services were seen here as a manner to enforce these emotional attachments to the company and its products. A reflection made by the M.Sc. student that conducted most of the design work in the case study was that the PSS Conceptualisation Methodology was well suited for the first analytical steps of the design process, but did not support the synthesis of product and service concepts well (Gonzalez 2008), more guidance was called for here.

Case study D: RiverSimple

The second company that the PSS Conceptualisation Methodology was applied at was the entrepreneurial hydrogen car company, RiverSimple. As in the Vitsø case study the process for the methodology was facilitated through four design workshops. As RiverSimple is a recent start up company and still in development the PSS design process was seen as investigations to the company's future service and distribution strategy.

In the first workshop the discussions were mainly focused around how to bring RiverSimple's Hyrban hydrogen car to the market. First of all the Hyrban's value proposition that would make it an attractive and competitive offer on the market had to be determined. Until then, the development of the car had focused on the technical feasibility of developing a cost effective car based on hydrogen fuel cell technology. The (Blue Ocean) Strategy Canvas visualisation technique as proposed by Kim and Mauborgne (2005) was used to compare how the Hyrban differentiated itself from potential competitors (incl. petrol driven cars, electric cars, shared car clubs, public transport and bicycles) on a set of vital performance parameters. Next, the imagined customer activity cycle was also discussed. What were the activities that potential Hyrban customers would go through (even before signing up) and how could RiverSimple best support these? Finally the actors necessary in the development, production and delivery of the Hyrban were identified and ideas were sought after why each of them would be encouraged to participate in the value creating network. Ideas regarding product life were not pursued as RiverSimple was determined to only offer the car through leasing so that all components could be kept in closed material loops and the company would retain their value.

The second workshop continued investigating these dimensions. The Strategy Canvas provided a good way of visualising Hyrban's competitive advantage and determining which parameters needed attention. Three different personas were identified as potential customers. Due to time constraints only one scenario for the persona's activities cycles were briefly played out. Likewise not much time was

spent on the mapping of actors and their relationships. Although not all dimensions of the PSS Conceptualisation Methodology were covered in this workshop, a large amount of information was shared and structured. The customer perspective of the value proposition and customer personas seemed to benefit as one participant commented at the end of the session, *“Ideally, this is where we should have started.”*

During the third meeting the documents from the last workshop were reviewed and amended. Launch strategies for the Hyrban were discussed in relation to potential actors for infrastructure development and funding. Out of this the outline of six preliminary concepts emerged.

The objective of the fourth and last workshop was to expand the concepts from the previous meeting and understand the opportunities and challenges of making each one feasible. Most of the concepts focussed on determining the context the Hyrban would be part of and how all the actors could be orchestrated and mutually benefit from the introduction and operation of a pilot fleet. Of the preliminary concepts three were seen as interesting to pursue.

RiverSimple’s design task is system design as well as business development. Their resources were at the time focused on identifying the right components and partners to redesign the entire hydrogen car system (e.g. hydrogen fuel distribution, repair and maintenance services, etc) and its actor network. For this purpose the PSS Conceptualisation Methodology seemed very appropriate. As a start up company without any products on the market they did not have any customer contact, although they did benefit from media attention and interest from the public. Here the methodology ensured that RiverSimple considered the customers’ perspective of the value perception and total experience of the system and not just the technical aspects of the car itself.

6.3 Systematic service-oriented ideation

Designers usually focus their problem-solving skills on developing physical products, and not complete systems that also include intangible service components. PSS approaches therefore represent both opportunities and challenges for companies and designers to conceptualise products and services in an integrated manner. It was observed in the PSS design course (case study A) that several of the student groups found it hard in the beginning to generate service-oriented ideas. The author noticed that pointing at other PSS examples did seem to help encourage the ideation of other ideas.

6.3.1 Morphological Method

Inspired by the Morphological Method, a common systematic method used in Engineering Design to generate new concepts, a similar approach was taken to support the conceptualisation of PSS. Originally developed by Zwicky (1966) it reduces a technical system into a set of characteristics or sub-functions, and each of these are varied individually and alternative means of fulfilling them are found. The alternative solutions are then structured in a table similar to the example shown in Table 6.1. Total solutions or concepts are then generated by combining these sub-solutions. Although not all combinations are feasible or even meaningful, the method does suggest a large number of concepts and helps designers to uncover most of the solution space.

Function/ Sub-system	Solution principles	1	2	3	4	5	6	...
1 Transfer Side Impact Forces		S1.1 Separate block 	S1.2 Integrated in trim 	S1.3 Multiple storage 	S1.4 Box a'la Audi 	S1.5 SPS-speaker 	S1.6 Box & SPS in seat 	...
2 Audio (principles, locations, geometry)		S2.1 Current location 	S2.2 Bass in side wall 	S2.3 Bass below seat 	S2.4 In parcel shelf Bass below seat and in parcel shelf 	S2.5 Bass in backrest 	S2.6 Upper front area 	...
3 Daily Life Storage		S3.1 Conventional 	S3.2 Folding pocket 	S3.3 Net (vinyl) pocket 	S3.4 X-drawer 	S3.5 Y-drawer 	S3.6 Z-drawer 	...
4 Open/Close Window		S4.1 Cross arm 	S4.2 Double rail 	S4.3 Wire in frame 	S4.4 Single wire rear 	S4.5 RAAB 98 pivot 	S4.6 Lamella side window 	...
5 Provide for Ingress/Egress		S5.1 Separate inner release 	S5.2 Inner release in armrest/grab handle I 	S5.3 Inner release in armrest/grab handle II 	S5.4 Inner release in grab handle I 	S5.5 Inner release in grab handle II 	S5.6 Touch release 	...
6 Structural/Architectural Principles		S6.1 Sheet metal 	S6.2 Frame- work in Mg 	S6.3 Super-integration 	S6.4 Plastic box closed box - structure as integrated part 	S6.5 Function module Function module integrated in structure 	S6.6 Flat-wire harness 	...
7 Provide for Ergonomic & Easy Assembly		S7.1 Clips 	S7.2 Hooks 	S7.3 Central sliding 	S7.4 Slide-in 	S7.5 Dry-side wire harness connection 	S7.6 Light colours 	...
8 Defrost Side Window		S8.1 Air flow from IP 	S8.2 Flow from belt 	S8.3 Flow from PDB 	S8.4 Concealing panel 	S8.5 From roof trim 	S8.6 Woven wires 	...

Table 6.1 An example of applying the Morphological Method. Here a matrix shows alternatives to the various sub-functions of a car door (Almefelt 2005).

By reviewing known PSS examples (e.g. Rolls Royce aircraft engines, JC Decaux rental bikes, Xerox photocopiers, etc.) and the PSS concepts generated in the PSS student design course, the various strategies that were adopted or employed for transforming a product into a PSS were identified (Tan & McAlloone 2006b). The identified strategies were then grouped into categories that described their characteristics. The intention with this exercise was to completely identify the service-oriented degrees of freedom with PSS approaches, based on an extensive number of empirical cases. In the same way that a morphological matrix in Engineering Design shows a variety of alternative solution proposals,

the characteristics of the strategies were lined up to show alternative strategies that could be considered for PSS conceptualisation.

6.3.2 A systematic variation method for PSS concepts

The strategies applied by students in the projects varied in each their own way. For example some projects focused on the extension of product and/or service offers to better fit the customer needs, whilst other projects focused on the new types of value delivery through partnerships with other companies and organisations.

The seven strategic PSS design characteristics were identified in the projects studied:

- *Resource efficiency strategy* – Based on the product's environmental profile (i.e. the type of environmental impacts and when in the life cycle they occur) a variety of resource (material and energy) efficiency strategies may be identified. E.g. as office furniture, such as desks and chairs, have their largest environmental impacts during raw material extraction and production, but hardly any during use, prolonging the products' life or ensuring recycling are the most sustainable strategies.
- *Responsibility or management of product life phase* – Increasing technological advances have made many products complex and require specific knowledge to be correctly installed, operated and/or maintained. If the need for these activities is only occasional for the customer, then companies may offer to take upon the responsibility of the physical products. E.g. in many offices today outside service companies are responsible for the installation, operation and maintenance of the coffee machines.
- *Support or management of customer life cycle activity* – Products that involve orderly handling during their life, either due to necessary technical upgrades or environmental concerns, entail constant surveillance and meticulous documentation. Many customers would prefer to outsource these activities and instead focus their efforts on their core activities. E.g. most chemical manufacturers offer Chemical Management Services (CMS) to their customers that ensure correct use, collection and disposal of chemicals.
- *Partner or collaborate with actor* – A manufacturer might not have the necessary competencies or access to the customers it would like to target with PSS approaches. In such cases the manufacturer may consider collaborating with other actors in the value chain (horizontally or vertically) to obtain access and/or provide the necessary competencies. E.g. to gain access to food retailers (e.g. supermarkets), a refrigeration controls manufacturer collaborates with local installers to provide monitoring and preventive maintenance services.

- *Availability of offering* – With the increasing integration of information and communication technologies (ICT) in products, it is possible to interact with products in new ways over time and space. ICT also facilitates the organisation and coordination of sharing the same products. This allows more efficient use of products. E.g. libraries nowadays allow users to check the online availability of books, CDs, DVDs, etc. and also reserve them for future use.
- *Degree of integration* – Products usually only cater for one or a few activities. Instead of focusing on the activities surrounding a physical product, companies should focus on the activities surrounding their customers. Even though the product might provide a core function, there are often activities before, during and after the use of the product that are just as essential to the customer. Companies may discover business potentials by aggregating and/or integrating how these activities are supported. E.g. For diabetics, insulin provides the core benefit, but a whole range of factors come in to play in the customer's experience: reminding the customer of when to take insulin, figuring out when to eat, measuring the glucose amount in the blood, noting how much insulin was delivered, etc.
- *Revenue mechanism* – It is given that in order for companies to exist the costs of manufacturing and delivering products or services have to be covered by the sales price, but how this price is constructed or determined is not necessarily given. Instead of one-off payments, companies may structure their sales to customers in different ways. Payment might be based on the availability of the product and/or service, based on how often the product and/or service is used, based on the end result of the use of products and/or services or even based on collateral for other valuable entities. E.g. in many cities the design, installation and maintenance of bus stop shelters are paid for by companies in exchange for exclusive rights to outdoor advertising space given by the city council.

Table 6.2 shows the identified characteristics of PSS strategies and some of their possible variations that companies may consider when developing PSS ideas. Some of the variations of each strategic characteristic may be seen as along an axis in one dimension (e.g. 'Availability of offering'), while others show distinctive alternatives in multiple dimensions (e.g. 'Degree of integration'). It is proposed that by considering alternative variations of these strategic characteristics new PSS solutions became apparent for designers. Although not exhaustive, Table 6.2 gives an overview of some of the most common PSS development possibilities for manufacturing firms. By combining the characteristics and their variations listed above, a multitude of development strategies may be conceived.

STRATEGIC CHARACTERISTICS		VARIATIONS OF CHARACTERISTICS													
PSS DIMENSIONS	Resource efficiency strategy	Minimise consumption of product		Minimise use of product		Increase utility of product		Prolong product utility		Close material loop		...			
	Responsibility or management of product life	Installation		Use	Maintenance		Repair	Upgrade		Reclaim	Disposal		...		
	Support or management of customer activity	Design	Operation		Finance	Training		Support		Monitoring		Optimisation		Consulting	...
	Partner or collaborate with actor	Suppliers		Distributors		Customers		Customer's suppliers		Customer's customers (end-users)		...			
	Availability of offering	Always available for the customer				Available at the customer when needed (serial use)				Available at certain times or places				...	
	Degree of integration	Core benefit alone			Multiple benefits aggregated			Multiple benefits integrated			...				
	Revenue mechanism	Transfer of ownership		Value based on per use		Value based on unit consumed		Value of the management of activities (outsourcing)		Value of taking responsibility of the use		Value of the result of use (performance based)		...	

Table 6.2 Strategic choices in PSS design and possible solutions structured in a morphological matrix (Tan & McAlloone 2006b)

At a later stage in this research, it was discovered that Meier & Massberg (2004) had already proposed a similar morphological chart for the development of service-oriented business models. The intention and approach are the same but their variable characteristics have their focus on services relating to production machinery. The objective in this research is to provide a more generic set of strategic characteristics.

In the conceptual phases of PSS development, designers may vary the strategic characteristics in relation to the actors and their context in an attempt to evaluate which service-oriented strategy would be the most appropriate for the company. Each characteristic represents a different way of describing a strategy on its own; but characteristics are to a certain extent often interrelated. For example the resource efficiency strategy of an offer is typically mirrored in how the revenue mechanism is structured, even though this is not always given. Some variations of the characteristics are better suited to others, whilst it is difficult to imagine the matching of others. The mapping of PSS strategic characteristics in such a manner is intended to allow new PSS ideas to flourish. By providing an overview of possible PSS strategies, designers may discover new degrees of freedom and opportunities not apparent within existing business models. Furthermore, it has long been established when designing that the evaluation of several alternative solutions aids in the identification of an optimal solution. Likewise by considering alternative strategies to PSS solutions, companies should be better suited to identify a strategy that fits their business context. The PSS development strategy matrix offers an overview of strategic

characteristics that companies may consider when offering their product and services. However it still leaves the challenge of navigation through the many possibilities as a task for designers. As with all design, knowledge of the stakeholders' context, needs and values, the social and technological possibilities and what is feasible for a company are all guides in creating a good solution.

The initial intent of this part of the research was to develop a comprehensive matrix that maps and identifies different PSS strategies. Although this morphologic method approach to PSS concepts does seem promising, it was not pursued further in this research project. Even though the base of the PSS development strategy matrix is student projects, it has yet to be verified if similar strategic characteristics can be seen in existing companies and business models, and whether the proposed classifications are appropriate for use in manufacturing companies.

6.4 Using the three dimensions to describe a PSS concept in a company

Besides the observations made from applying the PSS Conceptualisation Methodology as described above, the three essential dimensions of PSS concepts were also used to describe an integrated package of products and services that is currently successfully offered by a manufacturer (case study E – see Chapter 4 section for a more detailed description).

Case study E: SCA Hygiene Products

Together with relevant employees from the company (e.g. key account managers, care institution consultants, etc.), SCA's integrated package of products and services were described using the three essential dimensions of PSS conceptualisation presented in Chapter 5. This was done to support their communication both internally in the organisation and externally to customers on how they supported their customers and provided value to them. Although SCA had already developed and was currently providing their customers with a highly integrated PSS, they felt they lacked an overview and "language" to describe their service-oriented offerings. This was needed to be able to communicate to the market their value proposition. Moreover it was also seen as a means of developing their integrated offerings further with customers. This situation in SCA allowed the PSS concept dimensions to be tested as a means to contain and explain the essential aspects of what the company was offering to their customers and how they provided this.

Environmental analysis and total life thinking was already well established in SCA. Although the total cost analysis of their products included the consequences if a hygiene pad was used incorrectly (i.e. resulting in leaks and ensuing need to wash clothes), this was not considered in their analysis of environmental impacts. Due to their customers being predominantly public sector institutions, SCA was

already very well aware that they had multiple customers to serve. They distinguished clearly between (product-oriented) consumer (i.e. those with incontinence using their products) insights and (service-oriented) customer (i.e. those that purchase and help those that use incontinence products) insights. Their range of services (Plan, Coach and Monitor) corresponded to a customer activity cycle perspective, but was only limited to certain customer activities. The global service development team was, however, accustomed to studying their customer's activities to find opportunities for service concepts.

The modelling of the actor network proved to be very helpful for both SCA and their customers to understand the complexity of their interactions with each other, but also in relation to others in their own organisation. Through three “actor network game” workshops (one internally and two with customers) participants, in groups of up to six people, were asked to identify all the actors relevant to municipal incontinence care and map their relations to each other. This could be done fairly quickly (under 1½ hours) and provided the participants with an overview and common understanding of how all the actors and their activities influenced each other. There was a high degree of agreement amongst the groups in all the workshops when identifying the actors, so it is assumed that the most relevant actors have been taken into account.



Figure 6.3 Photos from one of the actor network game workshops with SCA and a group of their customers.

When sketching the relations between the actors, many of the groups did find it difficult to determine what constituted a relation between actors in the form of products, services or information. For example, for some participants an SCA report on the municipality's consumption of pads could be seen as all three types of relation. This goes to show that a common understanding of what is actually provided is not clear. The difference is determined by how value is perceived, is it in the transfer of a physical artefact, in the activity, useful knowledge, or is it simply necessary information for the system to function? Likewise, it was also noted that the actor network does not express very well when a relation occurs or needs to happen (i.e. the time dimension is not clear in the actor network). This often caused the actor network posters to be very

confusing and messy. Although it is the emerging common understanding, which is essential when modelling the actor network, it would be useful to visually distinguish what characterises the type of relationships between the mapped actors.

The modelling of the actor network permitted the participants to see their mutual roles in incontinence care and allowed them to openly discuss issues with each other and generate ideas of how to deal with them. For example these are some of the ideas that emerged from the workshop:

- Simplification of the information flows, processes and network for self-sufficient residents and residents needing care.
- Support to manage product stocks and direct delivery in the nursing institutions.
- Develop changes in practice for changing bed clothes when changing pads and in the case of leakage.
- Document the residents' satisfaction of municipal incontinence care and the incontinence products.

Directly after the workshop many of the participants felt inspired and motivated to investigate some of these opportunities further. After each workshop the participants were asked to reflect and provide feedback on the actor network as a method to develop the collaboration between SCA and their customers (i.e. municipalities). In general, the participants expressed that it was an appropriate, effective and exciting way for suppliers and customers to work together. As one continence nurse remarked, *"It's good to be able to structure things."* The complex system and activities of incontinence care could be structured, and problems and possibilities for collaboration uncovered. Or as a municipal employee dealing with strategic procurement contracts expressed, *"...it is really exciting and exposes a new way to see cooperation relations."*

6.5 Verification of the proposed dimensions of PSS conceptualisation

Related to the second research question, this thesis sets out to define the conceptual elements of PSS. In response to this, three different dimensions that could be used to identify and articulate the key aspects of PSS concepts were proposed. The analysis of the case studies in this chapter shows that the PSS dimensions 'work' and were useful. However, like other qualitative contributions in Design Research (Buur 1990) it is a challenging task to determine whether the proposed PSS dimensions are 'true' or 'right' (Andreasen 2008). There is no simple test that can be made to verify this. Instead the verification of the proposed PSS conceptual dimensions is done by comparing them to existing frameworks on general product concepts and the work of others on the elements of PSS.

In relation to Hansen and Andreassen's (2005) eight dimensions of a product idea (see Figure 6.1), the three proposed PSS dimensions are expansions of the general product idea framework:

- The *product life phase system dimension* elaborates the *product* and *technology* dimensions by extending them in time with the product's life.
- The *customer activity dimension* elaborates the *user/customer* and *need* dimensions by extending them in time with the user/customer's activities.
- The *actor network dimension* elaborates the *business* dimension by relating it to the *user/customer* and *need* dimensions.

The three PSS dimensions can therefore be seen as expansions of the description of a product idea in relation to a service-oriented strategy (i.e. the *strategy* dimension is already addressed by PSS approaches). As PSS are design objects, the *task* and *goal specification* dimensions must still be described to identify and formulate the PSS development activities that need to be executed by the company, customers and other partners. The three PSS dimensions on their own do not fully describe a PSS concept, but based on an existing product idea, they do seem to sufficiently identify and focus on the "*difference that matters*" with PSS concepts (i.e. the difference that distinguishes the service-oriented conceptual aspects) (Hansen & Andreassen 2003).

In relation to Mont's (2004) framework for evaluating PSS: *products, services, infrastructure* and *actor network* (see Chapter 2, section 2.4.3), the three dimensions are a more cohesive structuring of the key elements of PSS. Whilst the actor network dimension is the same as in Mont's framework, the product life phase system dimension considers both the product and infrastructure elements, and the customer activity dimension considers the services surrounding the customer. This allows the three proposed PSS dimensions to be causally related to each other and provides a more integrated and consistent description of the PSS concept. In addition, the proposed dimensions in the PSS conceptualisation model can be used more directly to support the evaluation of PSS concepts based on their business viability, technical feasibility, satisfaction of customer needs and the environmental impacts of the system.

6.6 Summary

An analysis through the three essential dimensions of PSS conceptualisation (product life phase systems, customer activities and actor network) appears to give a good understanding of how current products and systems 'work' and is also helpful in uncovering areas where the dimensions could be better aligned. A change in one of the dimensions influences the others and designers has to ensure that each of the dimensions of a new PSS concept support each other in order to

be consistent. The potential for innovation and greater environmental improvement is related to what part of the system is considered and can be manipulated.

When applying the PSS Conceptualisation Methodology with companies, environmental impacts were not the primary concern but value creation and business development was. Here PSS design was perceived as a systematic method for developing business plans. The three PSS dimensions together with the value proposition in unity seem to be compatible with the outline of a new business model. The starting point for analysis in companies need not be the product and its' life cycle, but could be any of the other dimensions. This did not mean that the product and its life cycle was not considered (for this would have overlooked many possibilities), but instead demonstrated that each of the other dimensions could also be used to structure the understanding of the current system.

Compared to a classroom setting, PSS design methodology in a company context has to deal with the management, organisation, coordination and integration of development activities. The methodology presented in this chapter does not address any of these issues and is limited to the development of PSS concepts and not the total process of bringing a PSS solution to the market. Likewise the degrees of freedom for PSS solutions in a company context are dependent on the business strategy, core competencies, structures and/or relationships and likely to induce change to existing business models. These aspects of PSS development are the subject of the following chapter.

7 PSS development

This chapter attends to the third research question by establishing PSS approaches in the context of design and development activities in manufacturing firms. Not all manufacturing companies and their business environment are well suited for PSS approaches. There are certain configurations of strategy, structure and environment that are more opportune to service-orientation than others. This chapter examines the coordinated product and service strategies and how they are developed within an organisational company context, through four case studies.

Based on the theoretical framework for PSS conceptualisation presented in Chapter 5, which structures PSS related design and development activities on various levels in the organisation and shows the dynamic interplay, the case studies are consulted to provide empirical insight.

7.1 Understanding development activities through their objectives, tasks and structure

In order to develop, sell and provide radically new business offerings, established firms choose to either create new independent business ventures, build up the necessary new capabilities within the current organisation's structure, or partner with other firms (Bower & Christensen 1995; Chesbrough & Rosenbloom 2002; Sawhney et al. 2004) (see Chapter 2, section 2.6.5). With PSS approaches manufacturing firms must decide what is best for them: to establish independent service-oriented business units; integrate service-orientation into all their business units; or partner with other service-oriented companies?

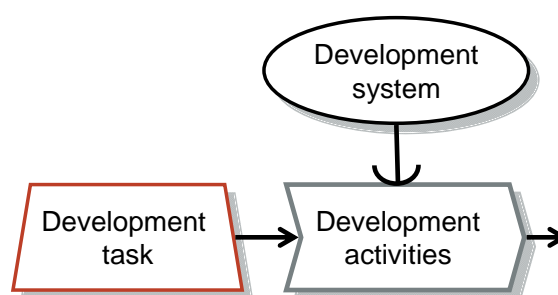


Figure 7.1 Development activities are influenced by the tasks and objectives they attempt to accomplish and the development system (e.g. people, knowledge, methods, etc.) in the company (Kirkegård 1988).

This is a question of the degree of integration needed in order to achieve the full potentials of PSS, and how these may be supported by the various development activities in the company or partnering companies. But before answering what organisational structure is most suitable for PSS approaches, the *development tasks* should be considered first (see Figure 7.1).

There is a difference between integrating departments, functions or management tasks (*the development system*) and introducing integrated procedures, processes and methods (*the development activities*) (Andreasen & Hein 2000).

In this light PSS approaches are not just about innovating the result of the development activities (i.e. the design object) in manufacturing firms, but they are also an opportunity to innovate the design organisation. Andreasen (2003) calls this '*design of design*' or how the design organisation is changed to fit the design task. Figure 7.2 shows a generic model of the dimensions determining what and how of designing. The shift to service-orientation for manufacturing firms requires an exploitation of key organisational capabilities, but at the same time PSS offerings allow the development activities to be arranged differently.

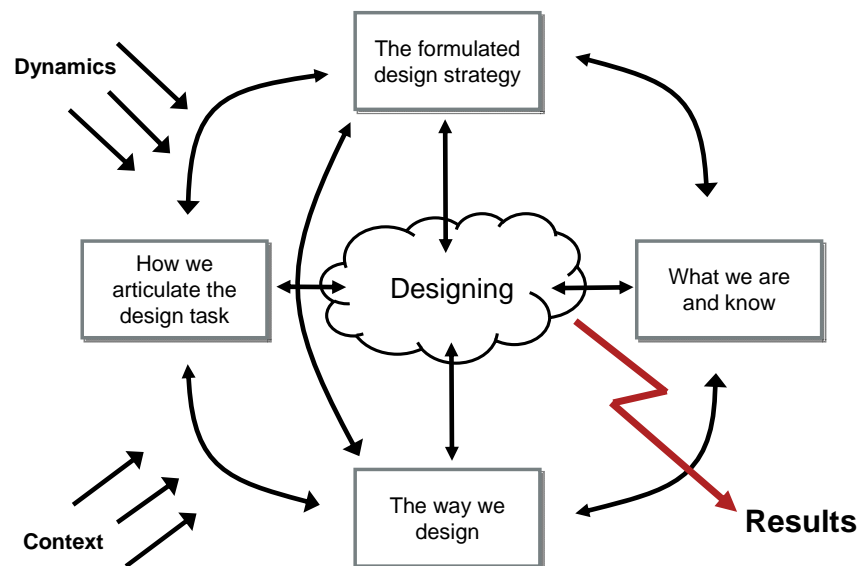


Figure 7.2 A generic model of the dimensions of “*designing the design process*” (Andreasen 2003).

It is the hypothesis of this thesis that the adoption of a PSS strategy for a manufacturing company leads to a set of new *opportunity parameters*, where degrees of freedom in design and development represent business opportunities that can be exploited (see Chapter 5, section 5.6.1). McAloone and Andreasen (2002) suggest the following opportunity parameters with PSS approaches:

- Re-invention of core business areas
- Increasing of competitive edge (customer lock-on)
- Greater control over the product throughout its lifetime
- Increased insight into the nature of the product and its use
- A path on the road to sustainability

Service-orientation in this sense encompasses more than the products and services being offered. With PSS approaches the development

activities in companies can provide a more integrated and higher level way of earning money than traditional product development. Different people in the organisation are involved in this process of shifting the development activities towards a higher position in the business value hierarchy. PSS development must include people beyond the typical product development hierarchy, such as product managers, heads of product development, project leaders and product designers. It should involve service development, portfolio managers, business developers and others involved in formulating the strategy of the business unit.

In the following, the objectives, tasks and structure of development activities related to PSS are studied in four companies (see Chapter 4). How are they organised, and how are the activities related to each other in order to develop products and services that support the business? The purpose of describing development activities in this manner is to apprehend how design and development in manufacturing firms may be coordinated to best suit PSS approaches. In order to integrate products and services in PSS, manufacturers must also consider how their development activities mutually support this new business strategy, otherwise they risk losing out on the full advantages of PSS approaches.

7.2 *PSS related design and development activities in companies*

The current design and development activities of the four case study companies (see Chapter 4) were investigated in relation to the proposed PSS development model (see Figure 7.3). The model attempts to promote the understanding of PSS development activities and their relations within an organisational company context. It is aimed at strategic management in manufacturing companies to provide a model for understanding the dynamic interplay between PSS delivery, development activities, business planning, partnerships and the formulation of service-oriented business strategy.

7.2.1 Case study B: Steelcase

Development activities related to strategy

Steelcase's mission is *"to provide a better work experience."* 'Better' in this sense relates to attributes such as productivity, efficiency, effectiveness, employee work satisfaction and health. The majority of the products they offer are characterised by being durable, long-life, high quality office furniture, where the purchase cost is high compared to its immediate cost of use.

In order to position them self on the market, Steelcase leverages its understanding of the social behaviour through user-centred design. WorkSpace Futures, the corporate research group, provides professional competencies and creditability that enables them to relate the value of

office space and furniture to their customers' business objectives and operational costs. Here investments in furniture are only a fraction of the total costs of employing people. The user-centred design approach is also instrumental for Steelcase to attain the ergonomic properties of their products.

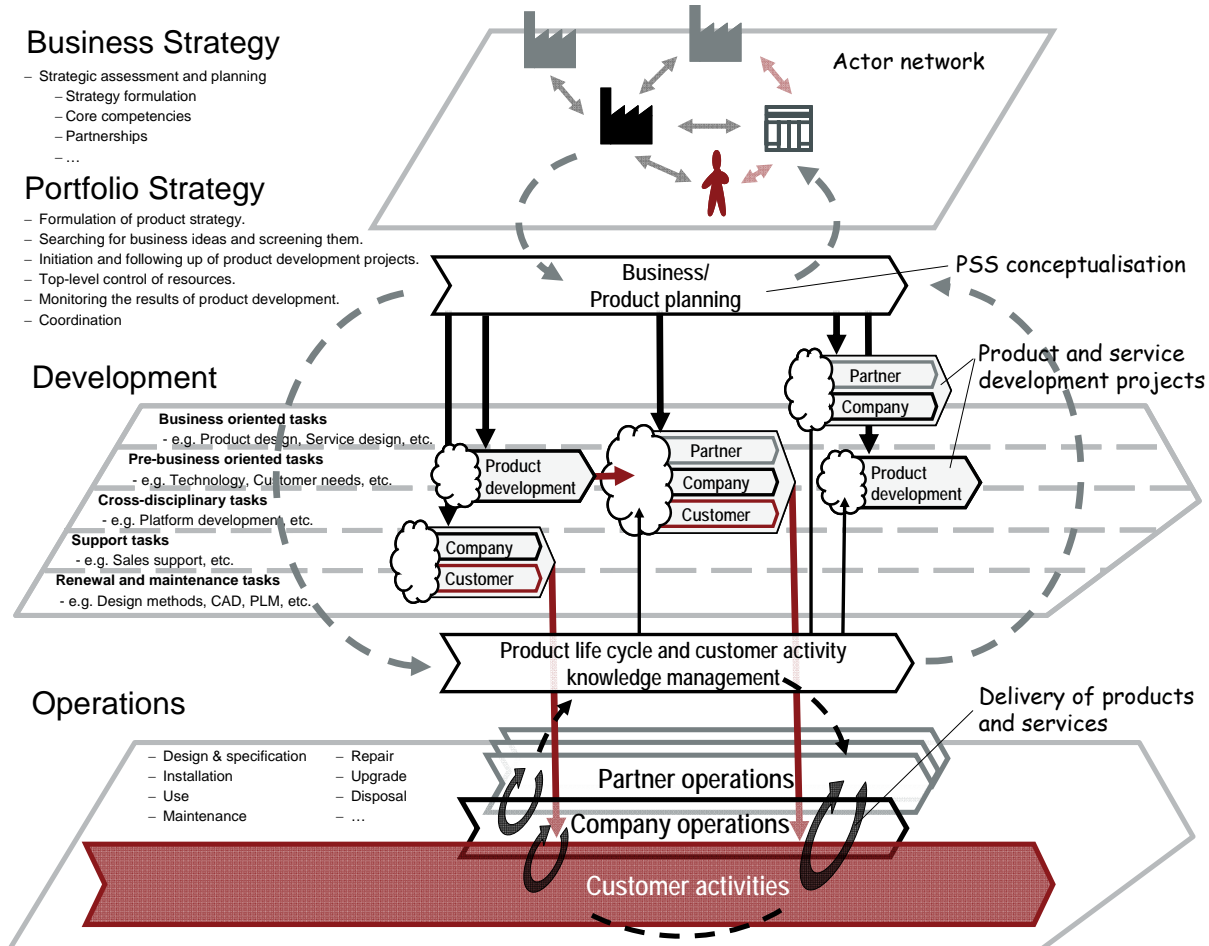


Figure 7.3 The proposed PSS Development model that shows the links between the development activities and business strategy (see Chapter 5, section 5.6.3).

In order to position them self on the market, Steelcase leverages its understanding of the social behaviour through user-centred design. Workspace Futures, the corporate research group, provides professional competencies and credibility that enables them to relate the value of office space and furniture to their customers' business objectives and operational costs. Here investments in furniture are only a fraction of the total costs of employing people. The user-centred design approach is also instrumental for Steelcase to attain the ergonomic properties of their products.

Similarly from an environmental perspective, Steelcase's competences in eco-design further support the product strategy. The greatest environmental impacts of office furniture are in the material extraction and production stages. Suitable eco-efficient strategies here are to extend

the product's life, increase its use, and/or limit the number of products produced/sold. Durability, repairability and recyclability are product properties that together with product-based services, such as asset management, repair and refurbishment, take-back, all support the extension of product life. Here it is possible to identify how these services can benefit from product properties that extend the product's life. Asset management, workspace planning and corporate consulting (services supporting the customer (Mathieu 2001a)) are examples of services that support the increased use of their products and can also result in a reduced need for furniture. In this case the role of product properties in relation to services is not so apparent, but the user-centred design approach is.

This correlation between business strategy, product properties and supporting services suggests an alignment between the product and service strategies based on Steelcase's core competencies in user-centred design and eco-design.

Organisation of development activities

The service development project the author was involved in at Steelcase was in its early development phase with more emphasis on research than development. The project was based out of the company's corporate research department WorkSpace Futures (WSF). Initiated as a university research collaboration, the business case for the project was not clear from the beginning. The project's general aim - to demonstrate and actively engage Steelcase customers in the importance of business and sustainability issues in the work place - was widely perceived as interesting and valuable, possibly spurred by of the sudden global awareness of environmental issues and climate change and in particular green building certification and rating initiatives. The project therefore enjoyed a high profile attention and encouragement from top management (e.g. Senior Vice President, WorkSpace Futures, MG, and President and CEO, JH) and external stakeholders (e.g. Fast Company (Breen 2007)), but it was not completely clear how the services would be offered to customers. As the Vice President of International Marketing Director, AWS, questioned, *"would it be sale of [consulting] services? Or free gift [to all]? Or a free gift with purchase [of office furniture products]?"* At the time of the project there was not a clear strategy for services in the company, but they were formulating a point-of-view on the topic using Steelcase's *"critical thinking approach"* (Hackett 2007). The corporate strategy was more focused on products and *"getting the product business right"* although members of the Steelcase Strategic Team acknowledged that services would play a part in the company's future, or as mentioned by Senior Vice President, MG, *"We have to move up the food chain. Profits are slim in manufacturing. We have to move in to services."* At the time of the case study, Steelcase was discussing whether the strategic intent of services was to drive the sale of products by bundling their value with

products, or to be offered as independent offerings that would be priced separately.

Despite the interest in the project from many different parts of the organisation, it had to compete for resources internally just like other development projects. Here the service development project faced two challenges due to the division of departments in the company. First of all, WSF can bring in new ideas and develop concepts to the organisation, but they do not have resources to implement these in the organisation. Projects in WSF should ultimately be 'sold' internally and handed off to the operating design and marketing organisation. Although it was a challenge to ensure effective knowledge transfer between departments in Steelcase, this process was formalised with stage-gate models demonstrating the path to be taken. As the service development project did not directly point to product sales and was more a service offering in nature, it had trouble finding a 'home' in the organisation as well as a development model and process it could adhere to. Service development in Steelcase was performed ad hoc and as such did not have its own budget like product development did. So although the delivery mechanism for the project was the ARC team, they did not have any development resources for this kind of project. Secondly, the project was thought of as a global initiative, but due to the structure of the company in a North American corporate segment and an International (countries outside the main North American markets) segment, it was not clear which segment would fund the project if both were to benefit from it. Thus the responsibility of the development task and its further development path were not well defined in the organisation.

The ARC team has a range of consulting tools and methods at their disposal. Some have been developed by Steelcase themselves based on considerable user research, whilst others have been adopted from other application areas to suit the office workspace. The tools and methods linked business issues to workspace design through an understanding of human factors, social behaviour and work culture. At the time of the project, the environmental perspective was lacking in the ARC team's consulting approach. Although all the consultants were highly experienced, these tools and methods were important in positioning the Steelcase ARC team as competent consultants in workspace planning and organisational productivity. Despite the fact that numerous researchers have claimed that workspace design can be a powerful leverage to boost employee satisfaction, health and productivity (Harrison et al. 2003), it still remains more a belief than statistical proof among Steelcase's customers. Steelcase is therefore constantly challenged to provide sufficient evidence of how workspace design (and thereby also their services) can support customer organisations in achieving their objectives. At the time there was no formalised

development process for consulting tools and services in Steelcase. As their name implies (Applied Research and Consulting) their services are derived from workspace research, but the actual development of their services were until then performed ad hoc. In addition, several Steelcase employees expressed that many of the marketing and consulting tools that had been developed by Steelcase over the years had not quite lived up to expectations when implemented, despite the tools did contribute with radical insights and approaches to understanding the workspace.

The delivery and application of ARC services are highly individualised and customised depending on the consultant and the client. Steelcase was interested in growing the consultancy business but needed to structure and formalise its consulting practice in order to communicate it both internally and externally. The ARC consultants expressed a need of a model for developing their business and services within the organisation as well as a manner to integrate an environmental perspective into their current offerings.

During the development project requests for collaborating on a tool that would link workspace design with business results and sustainability performance, were sent out to two other manufacturers of office workspace products (floor and ceiling solutions, and lighting systems respectively). Both companies expressed great interest in the project and could see the potential of the proposed tool. It is worthwhile noting that Steelcase enjoys the position of being the closest supplier to the actual users of the workspace, whilst design decisions on floors, ceilings and lighting are typically made before or without much interaction with the actual users of the workspace. This position in the supply chain limited these suppliers in their ability to demonstrate the user-oriented features and benefits of their products. Teaming up with Steelcase would therefore position them closer to the end-users and customers would potentially value them higher. Further collaboration with the companies was, however, not pursued due to limited project resources; legal issues about Intellectual Property Rights; and the prioritisation of getting the project adopted internally in the Steelcase organisation. Nonetheless, this suggests that there was a possibility of collaborating with other actors on the market to provide a comprehensive customer-oriented service offering.

In Steelcase the range of services, from financial services to workplace services to corporate consulting, is offered by different groups in the organisation (e.g. dealers, sales team, ARC, etc.). None of these groups have a dedicated service development function as such attached, but could initiate small individual development projects on their own if it was within their own budget. Issues occurred when the service development project demanded greater resources than was available in the individual service-oriented groups. WorkSpace Futures could

therefore only provide development resources to a conceptual degree and not execute development all the way to implementation. Unless there was direct top management support, no apparent system was in place to evaluate, coordinate and manage these service-oriented development projects and allocate resources accordingly.

Although the development project described in the case study in Steelcase faced difficulties it is not necessarily characteristic of the development organisation. Workspring, a PSS business venture project (see www.workspring.com), also based out of WSF was successfully implemented during the same time. Here the business case was much more clearly defined and top management more closely involved.

7.2.2 Case study C: Vitsoe and D: RiverSimple

Development activities related to strategy – Vitsoe

Vitsoe believes in *“living better, with less, that lasts longer.”* Based on this Vitsoe only offers a limited product range and variations, but, on the other hand, a fully modular, configurable and durable system that may be adapted to suit their customers (changing) needs. Like office furniture, Vitsoe’s products involve high purchase costs and practically no use costs. Their products position themselves on the market by its pure functional and industrial design qualities. Although they may seem to be priced high on the market, considering the (iconic) value it retains throughout its life, their products and supporting services do also make good economic (and environmental) sense in a long term perspective. To truly enforce this long term commitment Vitsoe encourages their customers to only buy what they need, as they can always buy additional products at a later stage. Furthermore, Vitsoe values a high level of service quality in all their interactions with customers which fosters loyalty and emotional attachment to the company and their products. Vitsoe’s business and product strategy can be said to be derived from the same ethos and their services further support this.

Development activities related to strategy – RiverSimple

RiverSimple aims to launch a hydrogen fuel cell car that is feasible, viable and affordable with current technologies in order to minimise the environmental impacts of personal transport. Currently the main barriers to hydrogen cars are the cost of fuel cells; hydrogen storage density; and access to hydrogen fuelling stations. Instead of trying to dimension fuel cells and hydrogen storage to existing cars, RiverSimple is redesigning the entire car, making it lighter, so the fuel cell power needed is reduced. To achieve this, advanced composites are used and although this increases production costs, it is compensated by the efficiency of the vehicle over its life. As the car will only be leased with fuel costs included, the car can be competitive economically on the market whilst allowing RiverSimple to benefit from fuel efficiencies and the (re)use of high-cost/high performance/long life components. The

distributed production strategy fits well with the characteristics of the vehicle and 'only sale of service' strategy. Finally, the development strategy of collaborative open source design is thought to be effective for a small company introducing a vehicle that is radically different from those of the big traditional car manufacturers. This is expected to also help in the general market adoption and the further development of the hydrogen car. Although RiverSimple has yet to launch their car on the market, their business, production and development strategies have been chosen to support attributes of their product, the hydrogen car.

Organisation of development activities

Case studies C: Vitsø and D: RiverSimple both describe PSS development in small companies with strong and inspirational business leaders. Both companies have a clear idea about the role of services in their business, and their active involvement in the concept development process ensured alignment between each of the PSS concepts and the company's strategy. In relation to the PSS development model (see Figure 7.3) the different levels of strategy, business planning, development projects and operations were always closely linked as it was only a small team performing all these tasks. Likewise, both companies do not have the need to have as formalised and structured processes for development as large companies do.

As a manufacturer Vitsø is atypical in that it does not develop new products, it only performs minor refinements and adjustments to its current range of products (whilst always being compatible with the original product system). The emphasis in development is instead placed on the services they offer to their customers and their supply chain.

An interesting aspect of RiverSimple's development activities is that the design task is from the beginning shared between several partners to encourage open source development of its vehicles. This is believed to accelerate the development and adoption of their hydrogen cars, but exactly how this will be leveraged, coordinated and managed is however not clear.

7.2.3 Case study E: SCA Hygiene Products

Development activities related to strategy

SCA is the world leader of incontinence products. They have a strong user-centred focus in their product development, which has resulted in innovative products that are ergonomic, more leakage secure and easier to use than most of the other incontinence pads on the market. However on the public sector institution market, customers are very focused on costs and tend to opt for low cost products. Disposable incontinence pads may not be the most expensive products but due to the quantities that are used, their costs can be substantial, and even more so when

considering the (indirect) costs of use (e.g. wages for care providing staff, washing of clothes in case of leakage, etc.). As SCA's incontinence products are priced slightly higher than their competitors, they instead focus on the customers' total costs of incontinence care by tracking consumption, and providing services to their customers on how to reduce this. In addition, minimising pad consumption by correct usage is one of the most effective environmental strategies for this type of product. SCA's services play an essential role in their business strategy. The services are delivered professionally and credibly by documenting their customer's pad consumption, as well as the satisfaction of incontinence care staff and pad users. A well developed information system supports the customer data collection, storage and analyses needed to provide these services.

SCA's business and service strategy for incontinence products on the public sector in Denmark are therefore well adapted to the properties of their products.

Organisation of development activities

In the case study of SCA and incontinence care, the importance of services and their development was already acknowledged in the organisation. Based on the launch of new types of incontinence products, it became clear to SCA that these needed to be accompanied with a 'total cost-oriented' service strategy to succeed on the market. A common corporate-wide approach was therefore applied to all service and training packages for nursing institutions around the world and resulted in a common service platform (TENA Services).

At the time of the case study SCA was in the process of determining the role of services in their otherwise traditional product-oriented business. Many opportunities beyond products were identified for incontinence care and management, but the focus was still on products and production. Although different points of view exist in the company and in top management, the category service director (BÅ) supports an integrated approach to product and service development and not separated entities: *"I believe that there are big advantages in integrating [products and services]. If we can get all product developers to think a little about services - how do you use the product? its packaging? etc. - then you will achieve spin-off effects in product development as well."*

In SCA the task of service development was different to that of product development, e.g. service development is aimed at customers (those that pay for incontinence products), whilst product development is focused on end-users (those with incontinence). Or as the service director (BÅ) points out: *"We [in service development] are not that formalised. We have an outline of a service development process, but we have said that in the beginning we want to be separated from [product development], so that we can better*

understand the unique dimensions of service development and not force it into any standard processes and thereby settle on a compromise. Soon it would be best to work in parallel tracks. We are looking for ways to speak together during the early phases."

Product and service development projects should not necessarily be conducted in the same way, but they should relate to each other and be considered in the early phases of development. This supports the proposed model for PSS development which advocates for coordination between product and service development projects, but does not necessarily imply integrated product and service development projects.

The SCA case study also shows that the development of services is not only performed centrally in the organisation, but is also conducted locally in the many parts of the organisation in individual countries and regions. The role of the central service development team is not to replace the local service development initiatives, but to coordinate and support them as well as spread knowledge and ideas across the organisation. Furthermore, services for nursing home contracts are also individually customised to suit the customers according to their needs and competencies.

SCA currently bundles the cost of services with its products. There are examples of contracts that separate product delivery from service provision, but these are not common. As SCA develops more services and emphasises the value of services, it also acknowledges that it will be problematic to continue with a product-based business model. In the near future, better and improved services will help the sale of products, but if increasing amounts of resources are put into the development and delivery of services, then SCA risks that the costs of this added-value cannot be born by products (see Figure 7.4).

By offering incontinence management services as a part of their value proposition, SCA can potentially save their clients from extra expenditures. SCA's customers might be willing to pay more for products for the extra services but only to a limit (one customer mentioned up to 10% more). Continued service-orientation demands a break from the traditional product-based business model. If SCA succeeds in documenting how much their customers can actually save by partnering with them, then part of the savings could justify the extra value of the services. This approach to business, where both parties have the same incentive, is characteristic for PSS.

For SCA's customers the extra costs of services is actually a barrier for PSS. This is because the end-users (those with incontinence) typically get their expenses for incontinence products reimbursed (e.g. the public social welfare system or insurance company pays for a certain amount of

pads per person). This form of financing is based on the consumption of products and does not support the financing of services that aim to reduce pad consumption. Generally this 'compartmental thinking' in (public) procurement organisations are a barrier for offering value-added services. Fortunately this is changing and the understanding for total costs is gaining acceptance in procurement. It is already common that public organisations buy external education and consulting services in other areas, so it is possible that services could become part of the total offering from a supplier. However, such an approach to providing integrated solutions is not common practice today.

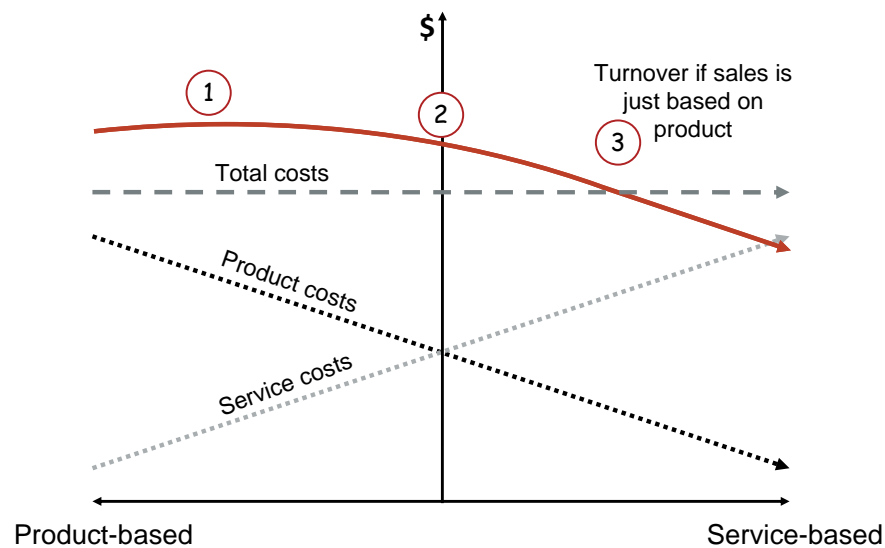


Figure 7.4 A representation of the dilemma with service-orientation when continuing with a product-based business model. If the value of services increases whilst still being bundled with services, there are limits to the profitability of the business model. Even if the product's total value increases (1) with more services, the costs of these services will also increase (2). At one point (3) the value of the total market offering will resemble more a service than a product.

An example of a service development project at SCA was TENA Online, a web-based system for ordering and tracking pad consumption. The online system allows customers (i.e. continence nurses and other care giving staff) to access directly and manage the individual accounts of all residents using pads, e.g. create, change and delete incontinence product orders. This eliminates many administrative routines that were necessary before for both SCA and their customers. It also allows nursing home managers and purchasers to easily track the costs of incontinence products and compare it with key performance indicators for incontinence care. Previously, much of this information was paper based, or difficult to access in the customers' own care management system. Furthermore, the system also allows SCA's consultants and Key Account Managers to perform analyses and create reports that advise customers on what they can do to optimise the consumption of incontinence products.

The development of TENA Online started as an idea in the management

team to streamline SCA's own internal processes. Together with SCA's corporate global IT function based in Munich, Germany, a web-based system was defined and a project brief put forth as a proposal for investment. This was then submitted to an internal corporate council responsible for the European region that evaluates development projects and allocating resources accordingly. The council evaluates project proposals on the basis of alignment with corporate strategy and business viability. Development resources are then awarded to the projects with most business potential. In this way the development investments do not affect the bottom line of the subsidiaries in the individual countries. TENA Online is a system specifically created because of the specific opportunities and market conditions in Denmark, but elements of it can be used in other countries as well and is therefore made available for any other part of the global organisation. It is the role of the global service development team to support the dissemination and local development of these online services.

The above is an example of how service-oriented development projects may be managed and is recognisable in the PSS development model proposed in this thesis.

7.3 Summary

This chapter has explored the third research question: How may PSS be developed in manufacturing firms? This was done by relating the case studies to the PSS development model proposed in Chapter 5. In each of the company-based case studies the relation between product attributes, development competencies, services and business strategy, were analysed. The analyses showed that they were all to a certain degree aligned and coordinated with each other to provide the resulting PSS.

The organisation of development activities was also investigated in each of the case studies using the PSS Development Model. In the case study on Steelcase it was observed how collaboration with partners and the use of user-centred design competencies formed the basis for new business, products and services. The company's corporate research group, Workspace Futures, performs most of the pre-business development tasks, but it is not always clear in the organisation how service-oriented projects can be developed. In relation to the PSS development model, the role of services in business planning was not found to be present in Steelcase. It is, however, not possible to say whether the difficulties experienced in the SWP service development project was due to this or simply an unclear business plan.

The case studies on Vitsø and RiverSimple showed examples of companies with a clear idea of the strategic implications of services, and how the development projects were in line with this. In both cases the integration and coordination of development activities and business

strategy was not an issue due to the small size of the companies and the active involvement of the business leaders.

In SCA Hygiene Products a high degree of service-orientation was already present and was being developed further. On a strategic level, SCA in Denmark is looking to form closer partnerships with their public sector clients. Products and services are not developed on equal terms in the company but there are systems in place that support the development of services. Following the PSS development model, SCA also provides a good example of how information about customers' activities provides value to both the customer and the internal organisation. And finally, the customisation of services to suit the individual needs and objectives of their customers is also present in their operations.

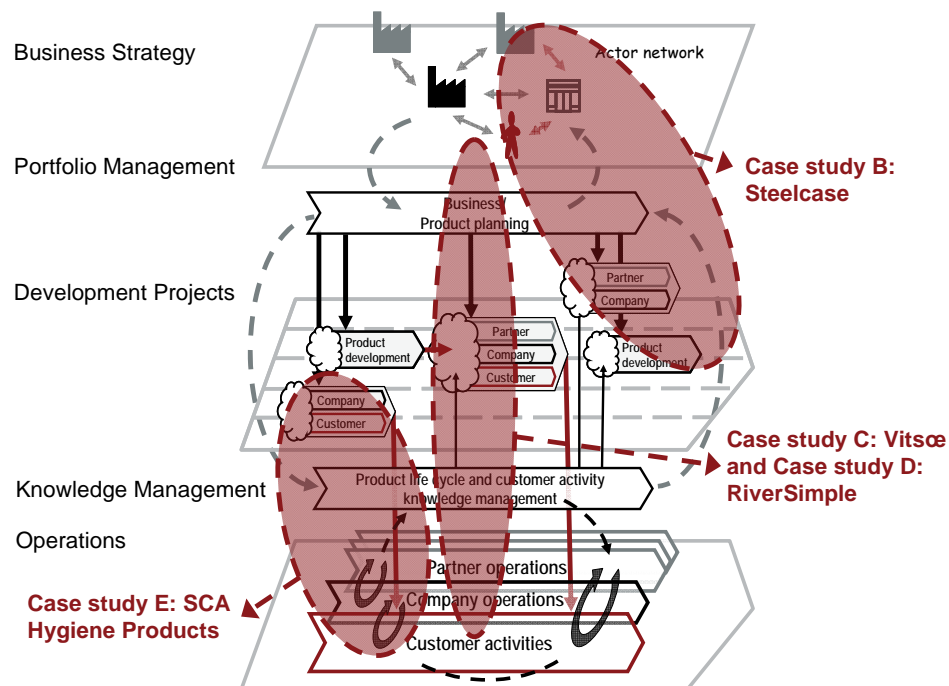


Figure 7.5 Each of the case studies dealt with different aspects of the PSS Development Model. *Case study B: Steelcase* was an example of a pre-business oriented task that also considered the orchestration of a different actor network. *Case studies C: Vitsø and case study D: RiverSimple* touched on all levels of the model: *Case study E: SCA Hygiene Products* showed how knowledge and on-going information about customers' activities was leveraged to deliver consulting services.

This chapter has demonstrated how the PSS Development Model proposed in this thesis can describe and structure various aspects of PSS development as observed in the case studies. Although this is not sufficient to justify the model, the evidence does show that the model is useful for understanding the organisational aspects of PSS development activities in manufacturing firms.

8 Discussion

The aim of this chapter is to discuss the findings in this PhD thesis in relation to validity and the existing knowledge in the field. The research in this thesis explores the synthesis and design-oriented aspects of PSS approaches. Until now PSS approaches have not been properly investigated in relation to the existing knowledge of design and development activities in manufacturing firms.

In the following the validity of the research is first addressed based on the research methodology described in Chapter 3. Then how the findings contribute with new knowledge is discussed.

8.1 Research validity

As mentioned in Chapter 3, Yin (1994) lists four criteria on which case study research should be judged upon, *construct validity*, *internal validity*, *external validity* and *reliability*. These are discussed in the following sections together with the role of the researcher in the case studies.

8.1.1 Construct validity

The first step to ensure construct validity was to clearly define the research questions and ground all constructs theoretically (see Chapter 1 and 2). To further support construct validity Yin (1994) suggests using multiple sources of evidence, establishing a chain of evidence and have key informants review the draft case study report. In each case multiple people were involved in the study providing different perspectives to the same things. In all the case studies multiple sources of evidence have been used and the information was cross examined to ensure the observations converged (*data triangulation*).

Most of the key informants in each case study were briefly told what the research objective was prior to the investigation, so they could verify whether the constructs were appropriate within their context (*investigator triangulation*). This of course poses a threat to the manner the informants responded to questions and spoke about things which could result in reflexivity (the informant attempts to fulfil the expectations of the researcher). Elements of this was observed as the author noticed in several cases that informants started describing current offerings and their activities as PSS, even though they had no knowledge of PSS prior to the study. It is difficult to determine whether this is due to unreliable responses or that the author's interaction with the respondent did actually provide a 'language' for understanding their own situation. Secondary informants were however not so well informed of the author's research so their responses were checked against the other responses.

In the short description of each case study, it should be apparent how valid instances of the theoretical constructs in this research are achieved in each case. In the case study from Steelcase and SCA individual key informants did have the opportunity to review the author's write-up of the case and provided comments. In the other three case studies the informants were not asked to review the observations and findings, but as those three studies were conducted together with other researchers, the author had the opportunity to discuss and reflect on the case studies with others. All main company contacts did however have a chance to review and comment on the case studies in the thesis.

8.1.2 Internal validity

Internal validity relates mostly to causal explanatory studies (Yin 1994). Although a highly relevant and legitimate objective, the aim of this research was not to show that a systematic PSS design methodology results in products and services with better sustainable (economic, social and environmental) performance. This is for now an underlying assumption built on the notion that systematic Engineering Design methods result in better products. If systematic design methods can be applied on PSS, then they too will result in better products and services. This research is exploratory and therefore it does not make much sense it attempting to assure internal validity.

Informants were however asked to reflect on their own impressions of the author's involvement and PSS methodology at the end of each study. In general the informants expressed enthusiasm and conviction that the methodology and PSS models and concepts did prove useful. Again, this effect can not be ratified completely as the relationship between the author and the informant could have biased the responses, but in all the company case studies it is assumed that a profit-driven enterprise would not spend extended amounts of time on a case study unless they themselves saw value in the interaction and research.

8.1.3 External validity

Case studies are often criticised because of limited *generalisability*. Although single studies are poor research strategies for *statistical* generalisation, they serve well when it comes to *analytical* generalisation (Yin 1994). Although multiple cases do support external validity, it is not possible to make any statistical generalisations based on the cases in this thesis. It was however possible to easily apply the theoretical framework in each case and use it to structure and analyse the context of each PSS. This would lay claim to the generalisation of the theoretical framework.

The threats to external validity relate to whether the findings are specific to the selected cases and their circumstances. The selection of cases was not random but based on opportunities that presented themselves

during the project, and how well they were a representation of the research object. The first case study regarding the PSS design course was of course not taken within a manufacturing firm's context, but as it was based on real manufactured products and focused on PSS concept design, it was very relevant for the study.

Although the second case study, the development project conducted with Steelcase was not formally formulated as a PSS development project, the company was familiar with the concept of PSS and had expressed that the move into services was eminent for them (Tan et al. 2007). The project originally rose from environmental efforts based in the product-oriented part of the organisation, but as the project progressed more service-oriented aspects were included in its development which resulted in the project being strongly service/customer relationship-oriented. Finally, the fact that the company chose to collaborate specifically with the author of this thesis, well aware of his prime research objective, leads to the belief that the company's general intentions and basic principles of PSS approaches were aligned.

The third and fourth case studies with Vitsø and RiverSimple, respectively, both qualify as manufacturing firms, albeit unique examples. First of all they both represent small enterprises. Second the companies' business logic was different compared with traditional manufacturing firms and already service-oriented. Vitsø had a very strong competence and understanding of the value of its service operations. RiverSimple was resolute that its cars could only be leased although it was currently focused on developing and testing its product and had not set up production and service operations yet. These case studies are therefore good examples of firms that are moving towards PSS, but do not have a systematic PSS development process in place. The fact that they are both small enterprises does not disqualify them. Initial PSS concept development would typically happen in a small team within a manufacturing organisation, and both cases encompassed how top management and strategic considerations influence PSS development.

The fifth case based on SCA Hygiene Products is very fitting as an example for a manufacturing firm developing PSS. It is however peculiar to business-to-government business, but this is not seen as being that much different to large contracts made between private organisations. In general the differences of the context of each case study (e.g. company size, industry sector, type of product, type of customer, country, etc.) is as much a verification that the PSS design methodology and framework is applicable in many different companies and situations, as it is a threat to the external validity.

8.1.4 Reliability

Reliability of research relates to if an investigator was to follow procedures and study the same cases, he or she would arrive at the same results and conclusions (Yin 1994). This is however not possible to actually do with Design Research as a case study's conditions and context is not homogenous with time (Checkland & Holwell 1998). Instead of the scientific research principle of *repeatability*, Checkland and Holwell argue for a principle of *recoverability* in action research. This means that anyone interested can recover the research process and trace its steps, and thereby understand how the findings were established. In Chapter 4 the author described and explained his research methodology in a manner that allows the process of investigation to be transparent for all. The notes, tapes and spreadsheets with the information gathered are not presented here, but if requested the author would be happy to share these materials.

8.1.5 Role of the researcher

The above has attempted to clarify and discuss the validity of the case studies in this thesis. Another aspect of the research methodology worth noting is the role of the researcher (Robson 1993; Van de Ven 2007). The author's role as a researcher changed in each case and affected the perspective and his relation to the object of study. In the first case the research had a role as a teacher and evaluator of the student's work. This allowed the author to be a dominant actor and influencer of the manner in which the students developed their PSS concepts. This is called for when trying out a PSS design methodology, but might not reflect the suitability of the methodology for the task as students tend to do as instructed to obtain good grades. In the second case the researcher assumed the role of a professional consultant in relation to Steelcase and spent extended amounts of time with the company employees and their context. This in social study jargon is termed '*going native*'. The researcher becomes so immersed in the context and is personally attached to the informants and the task that it results in reduced reflection and the broader perspective of what is actually going on. The author tried to be aware of this throughout the project, and as the process and results of the development project in the case study was not what the author was actually interested in his study, the observational biases are thought to be limited. In the third case study the author had a double role. Sometimes he acted as a process counsellor for the company and at others he was a co-supervisor for the M.Sc. student involved in the study. This allowed the author to remain fairly detached from the company whilst still accessing the rich immersion to the company context through the student. In the fourth case study with RiverSimple, the author was quite detached from the company's context. All the meetings were removed from the company's other activities and daily

work context. The intervention was also limited in time and number of interactions so the many contextual influencing were limited in this case study. On the other hand this case showed the ease of applicability of the PSS design methodology, which of course was mitigated by the author performing most of the design tasks himself. For the fifth case study the author had the role of a 'traditional' researcher as the majority of inquiry was done through interviews, and short company and customer visits. As the aim of this case study was to generalise the application of the PhD project's key concepts, this role seemed the most appropriate for the study. An interesting observation that was made in the various case studies was how the author did experience several occasions where he was perceived as an authority and thereby a veritable proxy for the company and its activities.

In line with the exploratory nature of this research, the empirical evidence provided in this thesis does not provide a complete description or explanation of the design and development of PSS in manufacturing companies. More research is needed to provide a more complete and detailed understanding of how integrated products and services can be developed. However, the case studies do provide in-depth understanding of the organisational and practical implications of PSS approaches which has been used to establish the following findings in this thesis.

8.2 Findings in relation to existing knowledge

In order to frame PSS approaches in relation to the existing knowledge in Engineering Design and Product Development, this thesis addresses three levels of understanding PSS:

1. PSS as a design object: *the PSS solution*
2. PSS as a design process: *PSS design*
3. PSS as an integrated development task following a coordinated business strategy: *service-oriented product development*

The distinction between these levels of synthesis in PSS approaches has never clearly been applied in the study of PSS which often lead to a simplification of how PSS could be developed in companies (Aurich et al. 2004b). Here business strategy and development, PSS conceptualisation and the execution of development projects were all bunched together and loosely referred to as PSS design. Based on the established and accepted theories in Engineering Design and Product Development, this thesis has outlined the design-oriented aspects of PSS.

This research ran in parallel with another related PhD project: "A systematic approach to service oriented product development" (Matzen 2009). The PhD project also investigated the development of PSS solutions. It took a similar approach to studying PSS as this research does, but

focused on modelling the service activities in relation to the PSS development activities. Based on the analysis of three case companies and their service delivery systems (two were suppliers of ship equipment and one was a global supplier of refrigeration components and systems), the synthesis of PSS concepts was found to benefit from the *“iterative detailing and concretisation of elements utilising three view domains, being artefact-, activity- and actor-based”* (Figure 8.1).

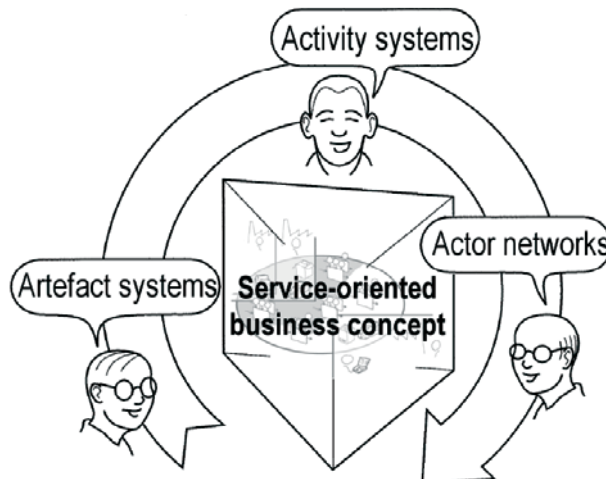


Figure 8.1 The three domains describing PSS concepts (Matzen 2009).

Matzen showed how specific changes to improve the support of operational service activities also resulted in changes to the life phase system, the activity process and actor network. These three domains are analogous to the three dimensions in the Model for PSS Conceptualisation in this thesis (see Chapter 5, section 5.4). There are however slight differences between the domains/ dimensions described. Matzen’s *artefact systems* (which correspond to product life phase systems in this thesis) also include the value propositions offered to customers (e.g. service offers are regarded as equal to product offers). In this thesis value propositions are the resulting perception of the product life phase systems, customer activities and actor networks.

In this thesis value propositions with PSS are not considered any different from value propositions in more traditional product offerings. PSS are merely just another mode to how companies deliver value to customers. Matzen’s understanding of *activity systems* is also broader and a more general view than the customer activity cycles in this thesis as it encompasses both customer and company activities. But this is more a question of perspective as this thesis takes the customer activities to be at the core of how value is provided, whilst Matzen is focused on service activities. Nonetheless the differences mentioned above are small and relate more to the perspective taken and definitions of terms than to different models. What should be noted is that both research projects provide different evidence to the same findings.

Furthermore in his thesis, Matzen pointed out that the development of PSS is a collaborative effort spanning across the organisation. The shift to greater service-orientation could be done through a gradual alignment of company activities with the customer activities on an operational, dispositional and strategic level (see Figure 8.2). This partnership-based business model of PSS development is also similar to the PSS Development Model in this thesis (see Chapter 5, section 5.6.3).

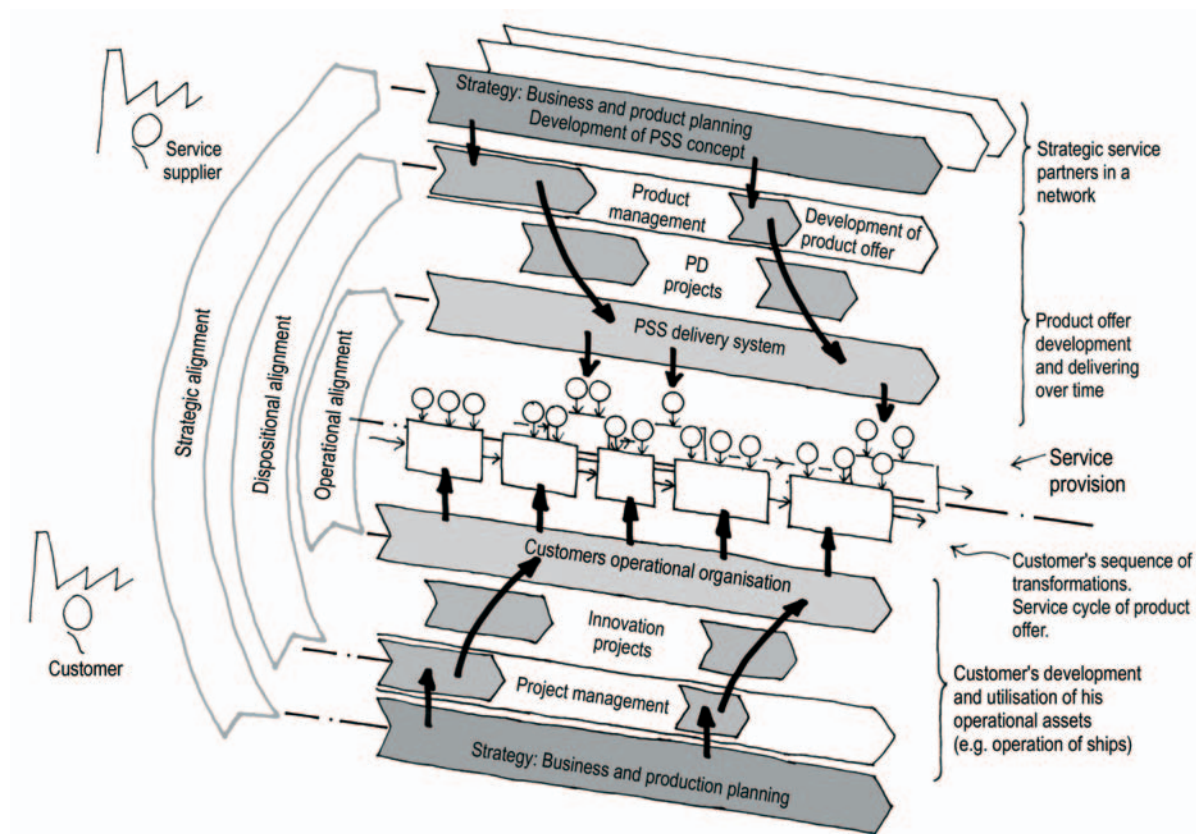


Figure 8.2 A partnership-based business model where customer activities are linked to the service provider on different organisational levels (Matzen 2009).

Both theses postulate that in order to fully exploit service-oriented approaches, PSS development needs to be considered on multiple levels of the organisation. Matzen's model however is built up from the service activities (where customer activities are matched with the company's supporting activities), whilst the PSS Development Model in this thesis focuses on the development activities in a company and then relates it to customers and other actors that surround the PSS.

It might not seem surprising that there exists many commonalities between Matzen's work and this thesis as both researchers worked closely together throughout their projects (see e.g. (Matzen et al. 2005; Tan et al. 2008; Tan et al. 2009)). The fact that both researchers worked so closely together does not contribute to the validity of the findings. But as each project had its own focus and different sets of empirical data, it is however remarkable that similar findings were made. It is not possible to prove that the researchers in their analysis were not influenced by

each other, but rather it is the opinion of the author that both research projects complemented each other. The process of working in parallel allowed both researchers to challenge each other with their own individual perspectives.

Finally, although existing literature on PSS development exists in other languages, such as German, French and Japanese, these have not been studied. However, the author has been in dialogue with several researchers from precisely these countries during the many workshops he has participated in (see Chapter 3, section 3.4). In general the papers that form the initial work and basis of this thesis (Tan & McAloone 2006a; Tan et al. 2007; Tan et al. 2008; Tan et al. 2009), have been broadly accepted as relevant and novel insight when presented to the academic community and industry.

8.2.1 Understanding PSS design and development

Relating to the first research question, this thesis found that Hubka's (1988) Model of the Transformation System could be used to describe services that directly involved the product through out its life (see Chapter 5). In order to grasp the full range of services, this thesis (based on McAloone's (2005) initial work on a systematic approach to PSS design) also considers the *customer activity cycle* during the design and development of products and services. Although both product life phase systems and customer activity perspectives are both well-established in Engineering Design (Olesen et al. 1996) and Service Marketing (Vandermerwe 1993) respectively, this thesis asserts that the understanding of both perspectives in relation to each other are fundamental for PSS. The reconciliation of both life cycle chains seems to be the key to sustainable consumption and production as both the supply and demand sides are represented. Furthermore, it was found necessary to provide an explanation for how and why the actors involved in both product life cycle and customer activities were motivated to engage in developing, providing and maintaining PSS offerings. The actor network perspective was however already established in the PSS literature (Manzini et al. 2004; Tukker & Tischner 2006).

When flipping the research question and asking, *how can traditional product development be understood through PSS?*, this research provides some interesting ideas to how the customer activity and actor network perspectives can also enrich the design and development of traditional products. A focus on customer activities and actor network can help product designers better understand the context in which their product will become part of (Vandermerwe 2000; Donaldson et al. 2006). It also reveals how customers and other actors can be actively involved in the design process. The expansion of Engineering Design to also include services has the potential to benefit product designers in their work.

8.2.2 PSS conceptualisation

With regards to the second research question, this thesis proposes a model for PSS conceptualisation that emphasises the three essential dimensions of PSS concepts: product life phase systems, customer activities and actor network (see Chapter 5). On their own, each of the perspectives describes a part of a PSS offering, but it is when the design object in each of the dimensions mutually supports each other that the potential for the desired economic, social and environmental benefits are revealed. This was apparent from the PSS design student projects, but also during in the case studies with Vitsoë, RiverSimple and SCA Hygiene Products (see Chapter 6). The coherence between the three dimensions helps determine how ‘good’ the PSS concept is. Furthermore, this thesis pointed at visual design tools that can be used to support PSS conceptualisation. This was clearly observed in the three companies where PSS modelling techniques were used.

The Model for PSS Conceptualisation is similar to the four models proposed in Service Engineering (Shimomura & Sakao 2006), but instead of attempting to codify the many variables and parameters of the system so they fit to a very functional and deterministic structure, the model and approach taken in this thesis uses graphical representations to create a deep and rich insight to each of the design dimensions and forms a basis for shared understanding in design. This is thought to be more appropriate for conceptualisation where many ideas are quickly simulated, analysed and evaluated qualitatively. The Service Engineering approach would seem better suited to more detailed modelling of PSS.

The three dimensions in the PSS Conceptualisation Model also completely describe PSS concepts in relation to Mont’s framework for evaluation of PSS (Mont 2004). Here the four elements: products, services, actor network and infrastructure are identified. The model in this thesis takes infrastructure into consideration in the product life phase system view. What is lacking in Mont’s framework compared to the proposed model, is the customer activities that give an understanding for the need and consumption side of PSS.

Furthermore, an outline for systematic PSS concept generation method inspired by the Morphological Method was also put forth. Other researchers have attempted to map out the service-oriented opportunities for product-oriented companies (Meier & Massberg 2004; Tukker & Tischner 2006), but without integrating the three essential PSS dimensions established in this thesis. Although promising, due to time constraints the PSS morphology table was however not tested in relation to if it could actually support the systematic development of PSS concepts.

8.2.3 PSS development

A Model for PSS development was proposed to address the third research question in this thesis (see Chapter 5). Based on how development tasks are typically structured in manufacturing firms (Andreasen et al. 1989), PSS approaches in a company context were studied through four case studies. In earlier PSS related research, the management, organisation and integration of development activities in a company was not addressed. Researchers dealt with PSS development in general and did not distinguish between the difference in activities of early conceptualisation phases or the executing and implementation of PSS. Likewise, aspects such as how development activities related to a manufacturing firm's organisation and strategy was also taken for granted (Johnstone et al. 2008).

Some researchers have studied the antecedents for service development in manufacturing firms (Antioco 2006; Gebauer et al. 2008) which provide an idea for what factors influence success when developing different types of services, but these do not provide an explanation to how development activities on different levels of the organisation can be related to each other to achieve the full benefits of PSS approaches. With PSS approaches there has to be a clear alignment between business strategy, product strategy and service strategy. Examples of this were shown in all the company case studies (see Chapter 7).

In the literature it is discussed whether service-orientation in manufacturing firms should be organised in a separate organisation in order to establish an independent business model, service strategy, culture and identity, or attempt to integrate service-orientation into the whole business (Matthyssens & Vandenbempt 2008; Mills et al. 2008). The PSS development model is supportive of the latter strategy as manufacturing firms risk missing out on the competitive advantages through the integration of products and services. The organisational structure that best accommodates service-orientation is however still unclear. The SCA case study points towards integrating service-orientation in the entire business unit, but there is not sufficient evidence to support this generally.

Although the Model for PSS Development is in accordance with how development tasks in manufacturing firms are organised, the company cases only provide support to parts of the model. The Steelcase case study endorsed the development activities related to business strategy (in collaboration with partners), development projects and operations (together with customers and partners), but the insight gathered on the portfolio management and knowledge management levels was insufficient to provide evidence for the whole model. The case studies with Vitsø and RiverSimple confirmed the effectiveness of coordinating

and integrating the multiple levels of development from strategy, development projects to operations, but due to the small size of these companies this was inherent to their nature. These case studies could therefore not provide much insight to how coordination and integration could be best supported based on the structure of the PSS development model. The case study on SCA provided a better rapport with the PSS development model. Here an example of how services can be developed to create total incontinence care solutions was given. The case study also showed the importance of being able to monitor and analyse customer consumption information by using an integrated IT system. Compared to Steelcase the role of services in the business strategy was better adopted in the organisation. Besides the close collaboration between company and customers the SCA case study did not demonstrate the involvement of other external actors in the development activities, but the actor network perspective did show the complexity of relations that SCA had to manage when dealing with their customers' organisations.

Based on the empirical research in this PhD thesis there is not sufficient evidence to determine whether the PSS Development Model acts as a comprehensive and appropriate theoretical framework for the design and development of PSS, but on the other hand, the evidence does not refute it either. The Model of PSS Development is an early proposal for understanding and structuring the many development activities related to PSS approaches in manufacturing companies. This is useful when addressing companies interested in pursuing PSS approaches, but also serves as a general model in design for how companies can collaborate closely with partners and customers in the development of new (product-oriented) business. However more research is needed to elaborate and justify this theoretical foundation.

8.3 Other interpretations of PSS design and development

This thesis applies an Engineering Design perspective to PSS design and development. This is appropriate for manufacturing companies as this understanding of product development is the most widely adopted. However, other explanations can be made from the observations of design and development activities in companies based on alternative research paradigms.

During the data collection process for the case studies in this thesis, the researcher took upon the role of either action researcher or participant observer and access was given to a rich amount of contextual insight. At the same time as the author was pursuing the research object, many other mechanisms that influence the development activities in companies were also in play. Aspects such as political processes between individuals and groups, the importance of 'champions' in the organisation, the social, cultural and contextual influences, etc. were

inclined to be filtered away with the Engineering Design research paradigm adopted in this research. The adoption of social research perspectives based on Science and Technology Studies (Latour 1991; Ingram et al. 2007) could be interesting for interpreting and analysing the observations made in order to discover if the same or other insights would have been achieved.

8.4 Summary

This chapter discussed the findings in this PhD thesis. Based on the research methodology described in Chapter 3, the validity of the insights of the empirical case studies was scrutinised.

- Construct validity was ensured by using multiple sources of information and allowing key informants and other researchers to review the observations.
- Internal validity was not assured as this research is explorative, but the researcher did try to determine if the findings were useful for the informants in the case studies.
- The case studies provided deep insight to PSS design and development but are still insufficient to claim general external validity.
- The reliability and quality of this research is based on the author's description and transparency in the collection and analysis of data.
- As the role of researcher played a big part in the research methodology the biases of this was discussed in relation to the validity of the evidence provided.

The findings of each of the research questions were discussed in relation to the existing theories and knowledge.

- A PhD project that ran in parallel with this research came to similar conclusions on the conceptualisation of PSS and the structuring of development activities in relation to customers and other actors.
- The understanding of PSS design through product life, customer activities and actor network perspectives was asserted as being both practical and useful.
- An approach to PSS conceptualisation was found appropriate for systematically generating service-oriented concepts that are both competitive and sustainable in relation to traditional product offerings.
- The Model for PSS Development proposes a structure for the development activities related to PSS approaches that is appropriate for manufacturing firms, but more research is needed to elaborate and justify this.

Finally the limitations of the Engineering Design perspective applied in this thesis were discussed. The influence of political, social and

contextual factors was not investigated in depth and could provide alternative or deeper understanding of the research phenomenon.

In general the findings correspond to the existing knowledge, but provide a deeper and richer understanding to the design and development of PSS in companies. Although the findings provide useful insights, this exploratory study has also exposed many issues that need further investigation.

9 Conclusion

Product/Service-Systems (PSS) approaches are service-oriented business strategies that manufacturing firms may adopt to gain competitive advantage, generate more business and fulfil customer needs in a more sustainable manner. This PhD thesis has investigated the synthesis and design-oriented aspects of PSS in manufacturing firms based on theoretical and empirical research. This chapter summarises the main findings of the thesis in relation to the research questions initially posed and identifies the contributions to knowledge.

9.1 Research findings

This thesis is based on the systematic and methodological approach to design derived from research in Engineering Design and Product Development. It investigates the design and development activities in manufacturing firms that lead to integrated PSS. Here three levels of service-oriented product development were considered in this thesis:

4. PSS as a design object: **the PSS solution**
5. PSS as a design process: **PSS development**
6. PSS as an integrated development task following a coordinated business strategy: **PSS approaches**

This distinction guided the literature review for establishing the theoretical basis for the research and identified the areas worthwhile investigating. The existing research in PSS design does not take into consideration the business strategy and development system that are typically already established in manufacturing firms. A combination of theoretical and empirical approaches to the research questions was applied to provide a framework and insight to how to conceptualise and develop PSS. Five case studies, four with companies, provided insight and evidence for answering the following research questions:

9.1.1 Q1: Compared to traditional product development, how can PSS be understood?

Traditional product development is concerned with the development, production and delivery of physical artefacts (products) intended for sale. What happens after the product is sold and how it is used, is typically less of a concern. PSS approaches, in comparison, are service-oriented and focused on the activity and knowledge associated with the product throughout its life cycle. PSS development is therefore an expansion of the product as a design object to also include its *life phase systems*, the related *customer activities* and the underlying *actor network* that develops and maintains the system. In this way both the supply and demand side of products and services are clearly represented. The value relations that determine the incentives of all the actors involved in

providing the PSS are also considered. These perspectives are fundamental to the understanding of PSS and provide an answer to how they can be more resource-efficient and competitive than traditional product-based business models. The synthesis aspects of PSS are further elaborated in the next two research questions.

9.1.2 Q2: How may PSS be conceptualised?

PSS are focused on the activities surrounding the product throughout its life and the customer. The research in this thesis shows that the analysis and modelling of solutions according to the three fundamental perspectives of PSS: product life phase systems, customer activities and actor network support the systematic development of PSS concepts. These perspectives together describe the conceptual aspects of PSS and allow them to be easily communicated and evaluated in a design team. Here visual modelling techniques representing the three perspectives proved to be powerful design tools in PSS conceptualisation both in student projects and in the company case studies.

Further research in the conceptualisation of PSS led to a proposal for a systematic variation method for generating PSS concepts based on the Morphological Method. Here seven strategic PSS characteristics were identified and variations for each suggested:

1. Resource efficiency strategy
2. Responsibility or management of product life
3. Support or management of customer activity
4. Partner or collaborate with actor
5. Availability of offering
6. Degree of integration
7. Revenue mechanism

Although this approach provides a good overview of the different configurations of PSS which companies may adopt, it was not tested with companies.

9.1.3 Q3: How may PSS be developed in manufacturing firms?

The development of PSS is not just a task of initiating a service-oriented development project, but requires careful consideration of a manufacturing firm's competencies, customers and partners in relation to business planning and strategy to reap the full benefits. For PSS in the context of a manufacturing firm, the underlying assumption is that it can capitalise on its substantial experience and expertise of its products, and thus can create service offers that would not be feasible for other players on the market. Given these strengths a manufacturing firm should start by considering its existing market and customers to determine where PSS approaches might hold strategic opportunities to leverage its competitive position.

Manufacturing firms must ensure that their business strategy, development competencies, product strategy and service offerings are aligned and coordinated with each other to provide competitive PSS solutions to their customers. The development of PSS therefore occurs at several levels of the organisation. On the top level a PSS business strategy is based on the company's core competencies (either on its own or in a partnership with other actors). The next level is business planning or portfolio management, where development projects are initiated and managed based on PSS business concepts. The third level is where development projects are actually executed. Here projects may be focused on products or service and involve relevant actors, either among the functional units in the organisation or external partners and customers. The portfolio management level ensures coordination and integration between projects so that the development efforts support each other to form integrated PSS. PSS approaches expand a company's responsibility and involvement with its products and customers beyond production and delivery. It is therefore essential for companies to capture the information related to the lives of their products and their customers' activities. This information can be analysed and used to provide value to their customers as well as used to learn more about the performance of products as well as their customers' needs and behaviours. Finally on an operations level, service-orientation requires an on-going adaption and development in relation to customer activities.

Based on empirical insights a Model for PSS Development has been proposed in this thesis. It depicts the five levels of the organisation where development activities have to be coordinated and integrated in relation to a service-oriented business model and strategy. The Model of PSS Development is an early proposal for understanding and structuring the many development activities related to PSS approaches in manufacturing companies. It does not provide a step-by-step guide to how manufacturing firms should develop PSS, but it is useful for identifying and coordinating the development activities on the different levels of the organisation.

9.2 Core contributions

This PhD thesis advances the knowledge in the fields of PSS research as well as Engineering Design and Product Development. Here the core contributions are:

- The framing of the synthesis and design-oriented aspects of PSS in the already well-established systematic and methodological approaches in Engineering Design and Product Development.
- An exploration of the expansion of the design object beyond physical products to also include service design.
- The identification of the fundamental perspectives of PSS design concepts, product life phase systems, customer activities and

actor network that allow designers to systematically work towards competitive and sustainable PSS solutions.

- A set of visual design tools that allow each of the fundamental perspectives of PSS design concepts to be easily modelled.
- The mapping of design and development activities associated with PSS approaches in manufacturing organisations based on empirical case studies.
- A model for structuring PSS development activities in manufacturing firms so that ensure the business strategy, development activities and PSS solutions are coordinated and aligned.

Finally this research into the service-orientation of manufacturing firms also contributes to the traditional product-oriented design and business development. The findings in this thesis support the understanding of the context and system products become a part of as well as the development system involving customers and other external partners.

10 Perspectives

The objectives set forth in the beginning of the thesis were to 1) establish a theoretical foundation for the systematic and methodological approach to PSS design; as well as, 2) propose strategies and methods for manufacturing firms that wish to adopt PSS approaches. This chapter reflects on the research and findings presented in this thesis, and considers its implications and points to areas worthy of more research.

10.1 *Reflections on the research project*

Throughout the PhD project the author experienced extensive interest from other researchers and companies in the topic of this thesis. The application of ‘design thinking’ to both sustainable development and business development is perceived as a highly relevant research endeavour for industry, but also society in general. This research exposes many opportunities for how manufacturing companies could improve their value propositions in a more sustainable fashion through service-orientation. However, in practice the actual shift to these new business strategies is not a trivial undertaking and firms face many barriers and obstacles when implementing service-oriented strategies. At the same time, the verification of the theoretical findings of this thesis in relation to proposing a general prescriptive method for manufacturing firms posed a difficult challenge. The answers provided in this thesis are not conclusive, more research is needed, but it is a step on the way.

10.2 *Implications*

The findings in this PhD thesis instigate implications that are relevant to industry, research and education. These are presented in the following:

10.2.1 *Industry*

Service-oriented product development represents substantial business opportunities for manufacturing firms. Although still in need of verification of how they improve the development of integrated products and services, this thesis provides a set of design tools, *Product Life Gallery* (see 5.5.1), *Customer Activity Cycle Modelling* (see 5.5.2), *Actor Network Modelling* (see 5.5.3) as well as a morphological method to PSS ideation (see 6.3.2) that can easily be applied in companies. These tools are not just appropriate for companies interested in adopting PSS approaches but just as relevant for product-based business development.

Furthermore, the identification and structuring of development tasks and activities related to PSS approaches help communicate to companies how they can coordinate and integrate their business strategy,

development competencies, product strategy and service offerings to their customers.

10.2.2 Research

This thesis frames the relatively recent research in PSS with the established theories and models in Engineering Design and Product Development to provide a systematic and methodological approach to the design of PSS. The identification of the fundamental perspectives of PSS design concepts, product life phase systems, customer activities and actor network, provide a good understanding of the supply and demand aspects of products and services key to Sustainable Consumption and Production.

The Model for PSS Development activities in manufacturing organisations is an initial step to better understand the interrelationship of these activities and how they can be structured. It can serve as a basis for more empirical-based and in-depth research to how manufacturing firms can develop integrated products and services.

In addition this thesis expands the theory and knowledge in Engineering Design to also include non-physical design objects such as services and business models. Further research here will help advance the understanding of general design theory.

10.2.3 Education

Teaching of PSS design is already part of the curriculum of the Design Engineering programme at the Technical University of Denmark (see Case study A, Chapter 4, section 4.1) as well as a few other learning institutions. But in order to prepare the future generations of engineers and designers, students need to be equipped with the skills necessary to create a more sustainable society. Here a broad dissemination of how to design and develop sustainable PSS solutions in engineering and design schools could be effective. This thesis provides a set of initial models and design tools that could be used for teaching PSS design.

Finally in the teaching of 'traditional' product design it was observed that the design tools presented in this thesis would also seem to benefit designers in their understanding of the context and system products become a part of.

10.3 Suggestions for future work

This thesis should be viewed as a step towards consolidating the research in PSS with the established and accepted theories in Engineering Design and Product Development. The research performed here has been exploratory and helped build theory in the field. In order to provide more clarity on how manufacturers can successfully make the shift from product-orientation to service-orientation, more research is

needed to back these findings. The following is a list of areas in want of more investigation:

- *An Engineering Design approach to service design.* The systematic and methodological approach to design that is well established in Engineering Design research has yet to embrace the design of services. Research is needed to assist engineers and designers to be just as skilled with service design as they are with product design.
- *Collaboration with customers and users in PSS development.* Customers and users represent valuable resources that can be actively employed in the development and delivery of PSS. However, methods and processes for how companies can effectively and efficiently manage the different roles and responsibilities when working together in broad actor networks are not well developed.
- *Capturing and managing knowledge in PSS development.* Knowledge of product life and customer activities is often a prerequisite to PSS approaches. There is a need for models, methods and tools that enable the capture of design relevant information of product life and customer activities to support the development of PSS solutions.
- *Verification of PSS design methods and development processes in manufacturing firms.* Although a challenging task, the design-related tools, models, methods and processes proposed by researchers in PSS need to be evaluated and their effects on business verified as it is required (or at least should be!) in Engineering Design and Product Development. More empirical studies of PSS development in manufacturing firms are called for.
- *Management of customer consumption.* Manufacturing firms have traditionally succeeded by selling as much as they could produce, but this approach to business compromises the planet's natural resources and environment. In line with research in Sustainable Consumption and Production, there is desperate need for more research to how companies can be successful by reducing their customers' consumption whilst still satisfying their needs.

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Manufacturing companies have traditionally focused their efforts on designing, developing and producing physical products for the market. Today, global competition, outsourcing and legislation commend that companies take greater responsibility for their products. This is driving some manufacturers to shift their business strategies from selling products (e.g. photocopying machines) to the provision of services (e.g. document services). Instead of the product itself, the activity and knowledge associated with the use of the product is perceived to be of more value to customers. In the research community, service-oriented approaches that embrace this change of business focus from individual products to total integrated customer solutions are termed Product/Service-Systems (PSS).

This research addresses the systematic design and development of PSS solutions in manufacturing firms. The development activities of products and services in four companies were studied. By considering three dimensions of PSS – the *product life phase systems*, *customer activities* and the *actor network* – it is shown how companies can systematically conceptualise PSS and realise their sustainability (i.e. business, social and environmental) potential.

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DTU Management Engineering
Department of Management Engineering
Technical University of Denmark

Produktionstorvet
Building 424
DK-2800 Kongens Lyngby
Denmark
Tel. +45 45 25 48 00
Fax +45 45 93 34 35

www.man.dtu.dk